

THESES

présentées à l'Université de Nancy I
pour l'obtention du titre
d'Ingénieur Docteur
par

Noël MIDOUX
Ingénieur E.N.S.I.C.
Licencié es Sciences

Première Thèse

**ETUDE DE LA DISPERSION AXIALE DANS LA PHASE GAZEUSE
DES COLONNES A GARNISSAGE**

**INFLUENCE DE LA DISPERSION DANS LES DEUX PHASES
SUR L'EFFICACITE DU TRANSFERT DE MATIERE**

FIGURES

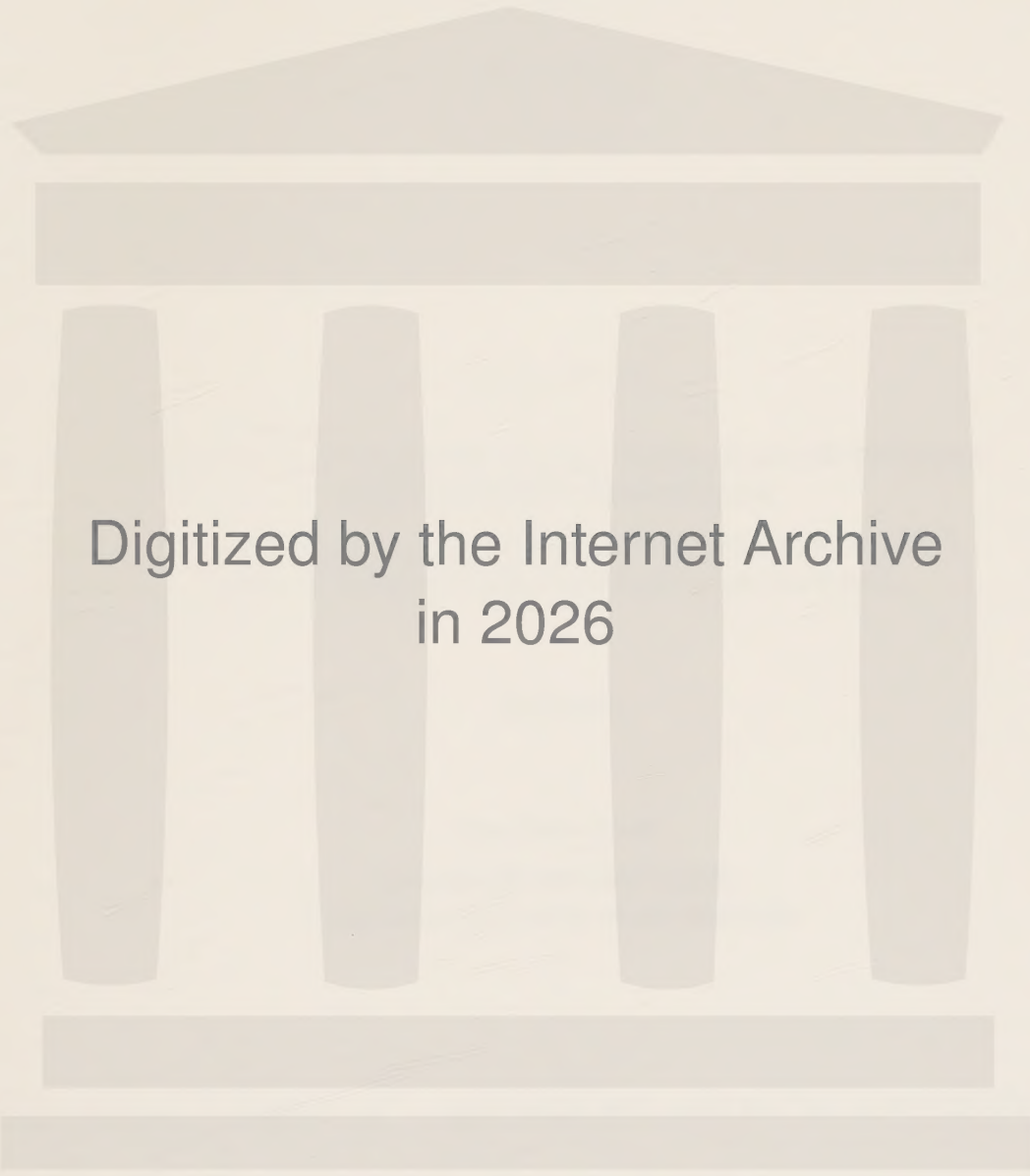
Deuxième Thèse

**LE POMPAGE PARAMETRIQUE :
NOUVELLE METHODE DE SEPARATION**

SOUTENUES PUBLIQUEMENT LE OCTOBRE 1971, DEVANT LA COMMISSION D'EXAMEN

Membres du Jury :

MM.	P.	LE GOFF	Président
	J.	VILLERMAUX	Examineurs
	C.	PROST	
	J.C.	CHARPENTIER	Invité



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FIGURES

Deuxième Thèse

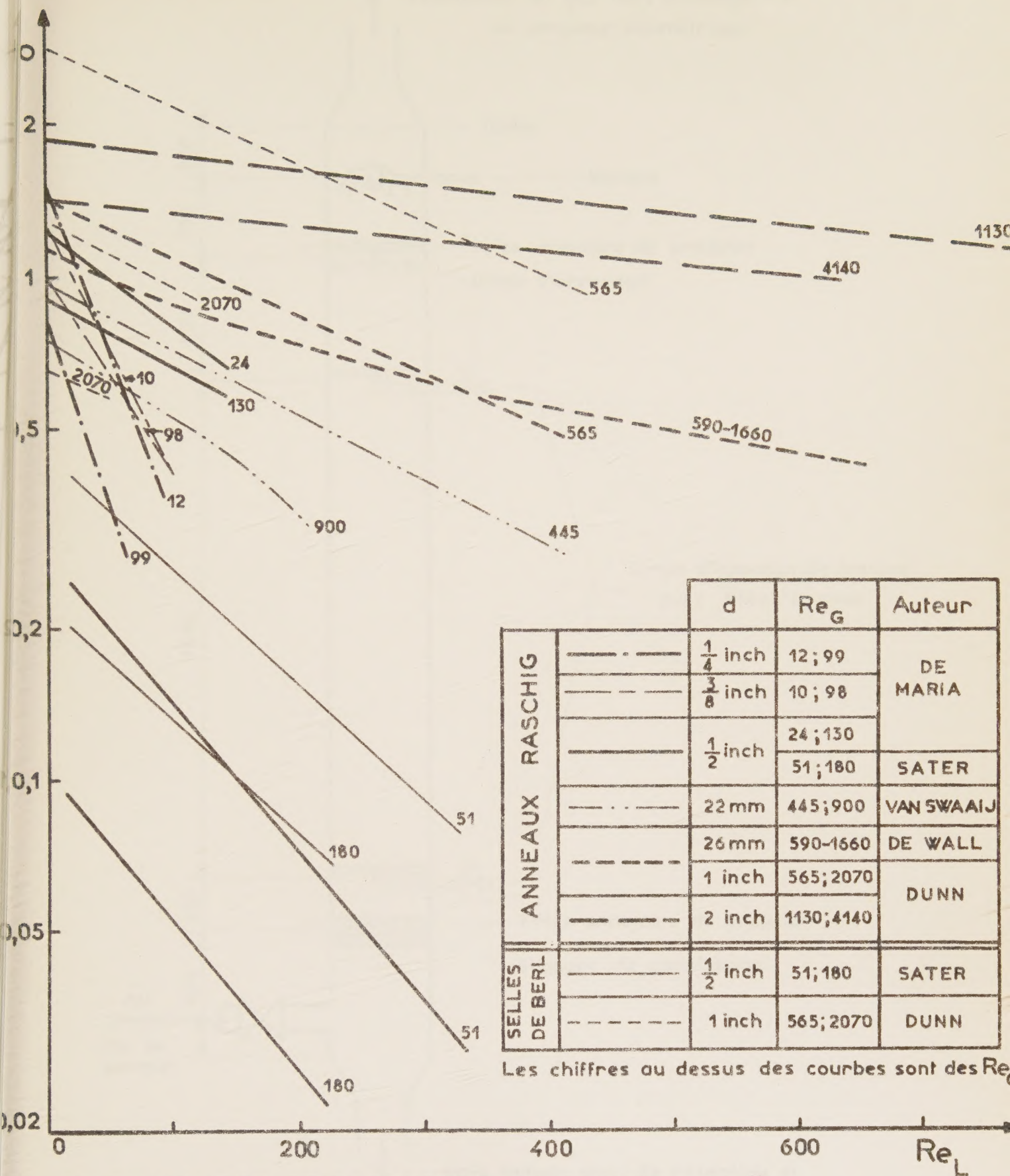
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**Fig. II-1: NOMBRE DE BODENSTEIN EN FONCTION DE Re_L .
RESULTATS DE LA LITTERATURE.**

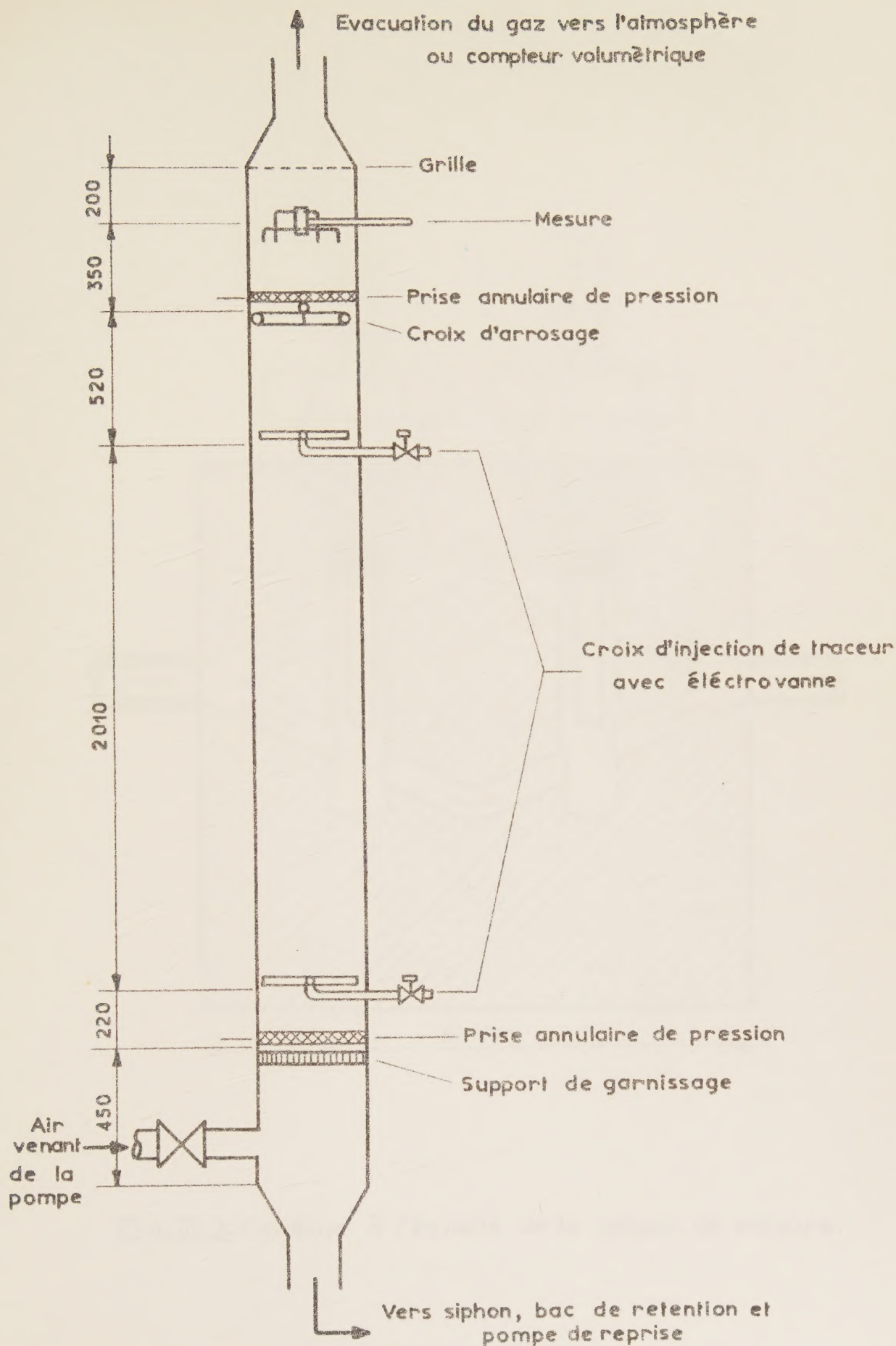
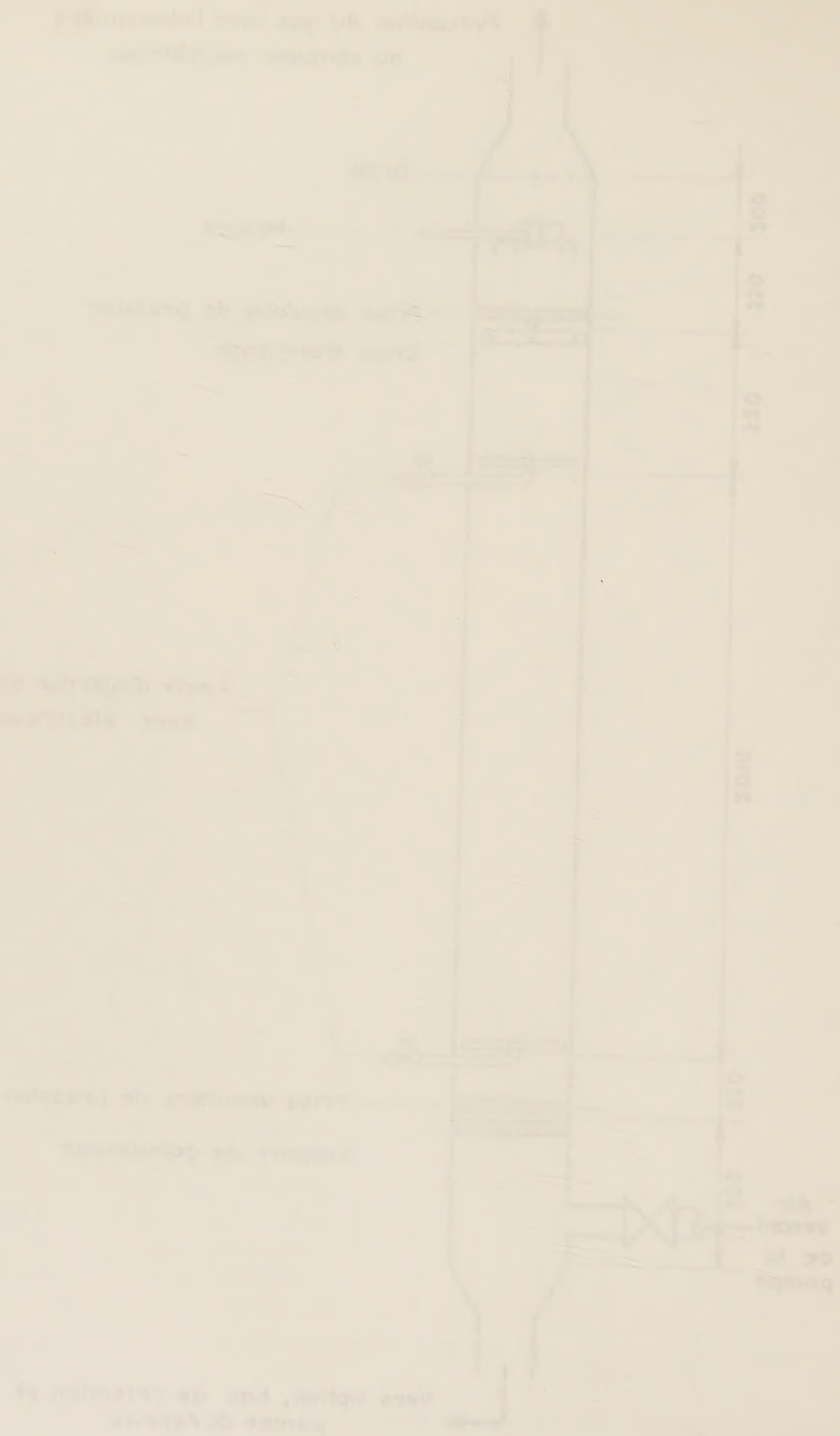


Fig.III-1: SCHEMA DE PRINCIPE DE LA COLONNE.

FIGURE 1 SCHEMA DE PRINCIPES DE LA COLONNE



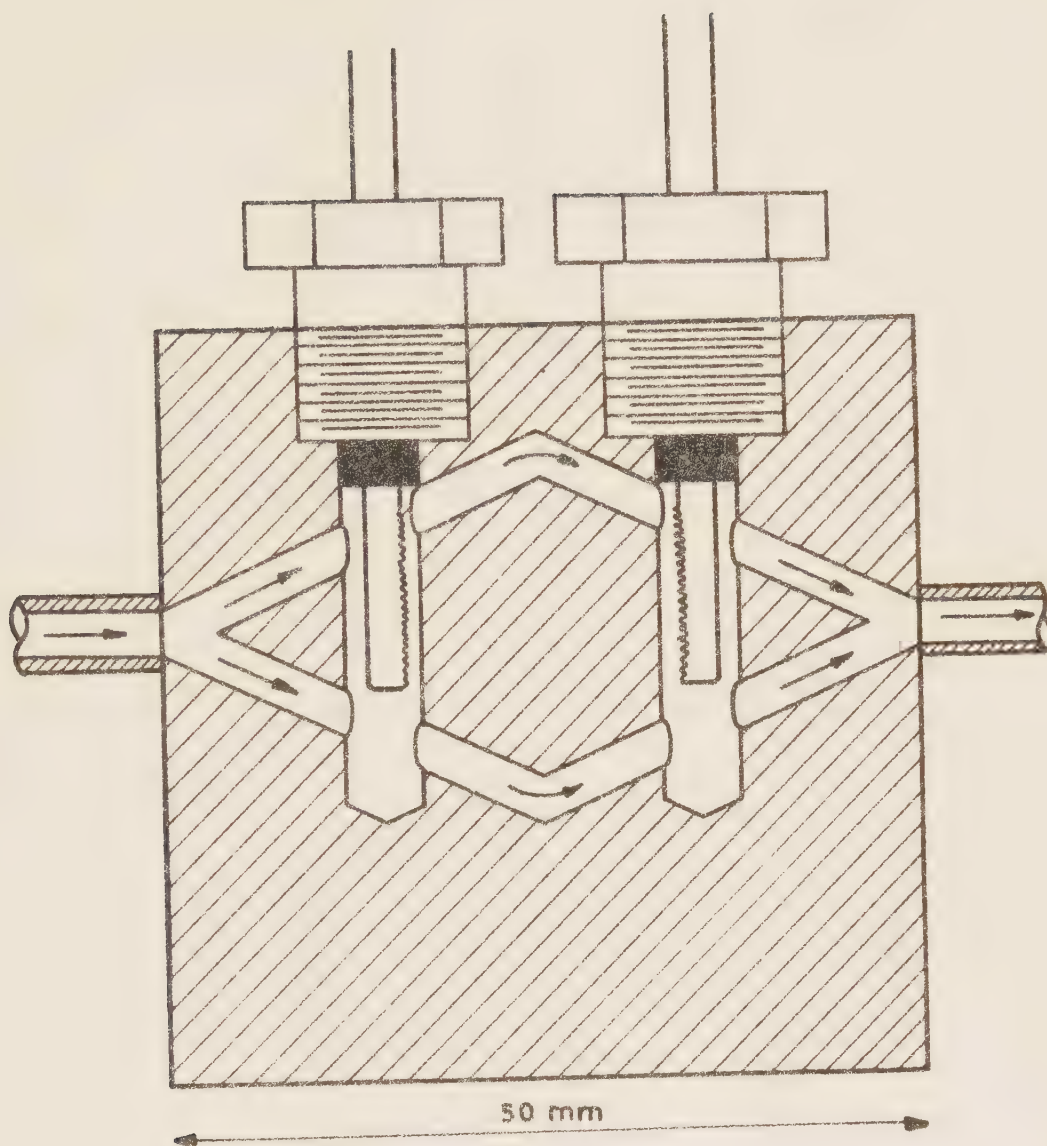


Fig. III-2: Schéma à l'échelle de la cellule de mesure.



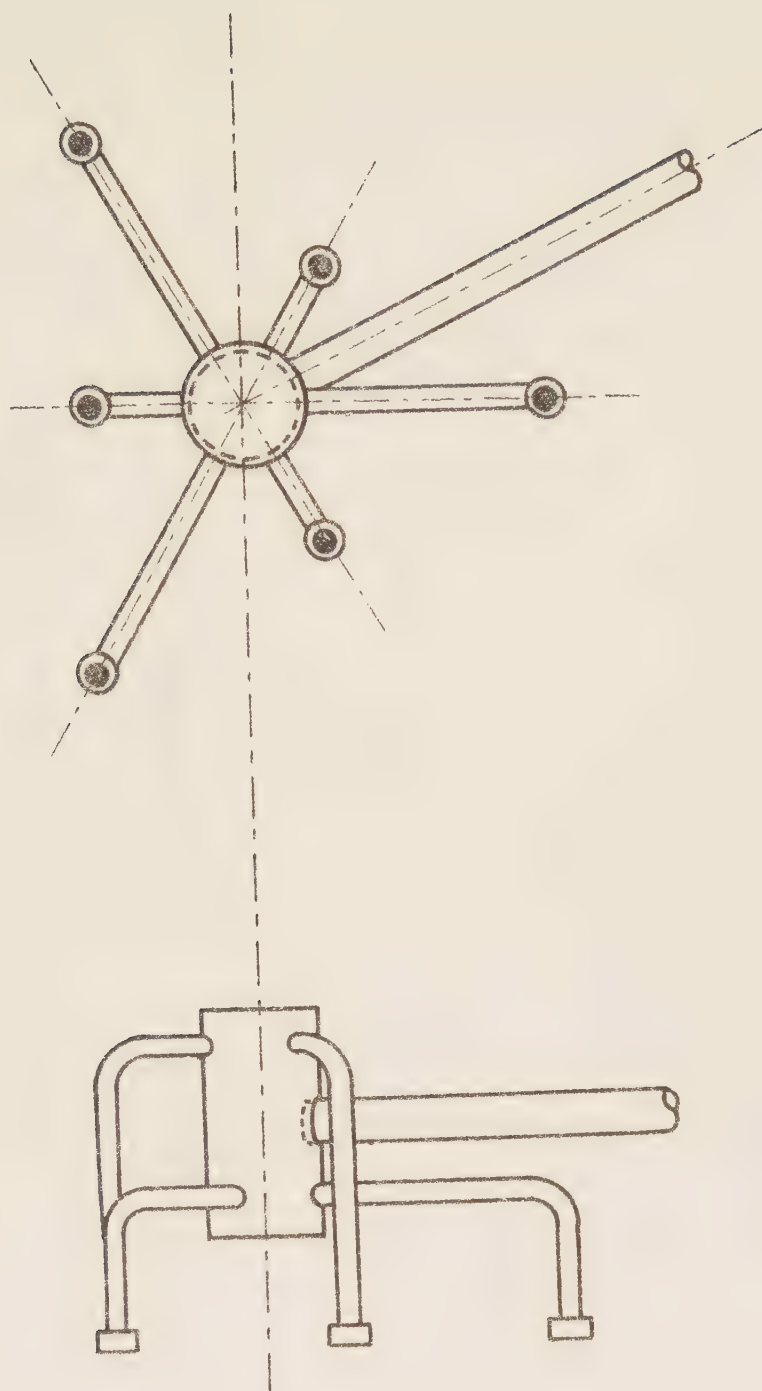


Fig.III-3: ORGANE DE PRELEVEMENT DU GAZ.



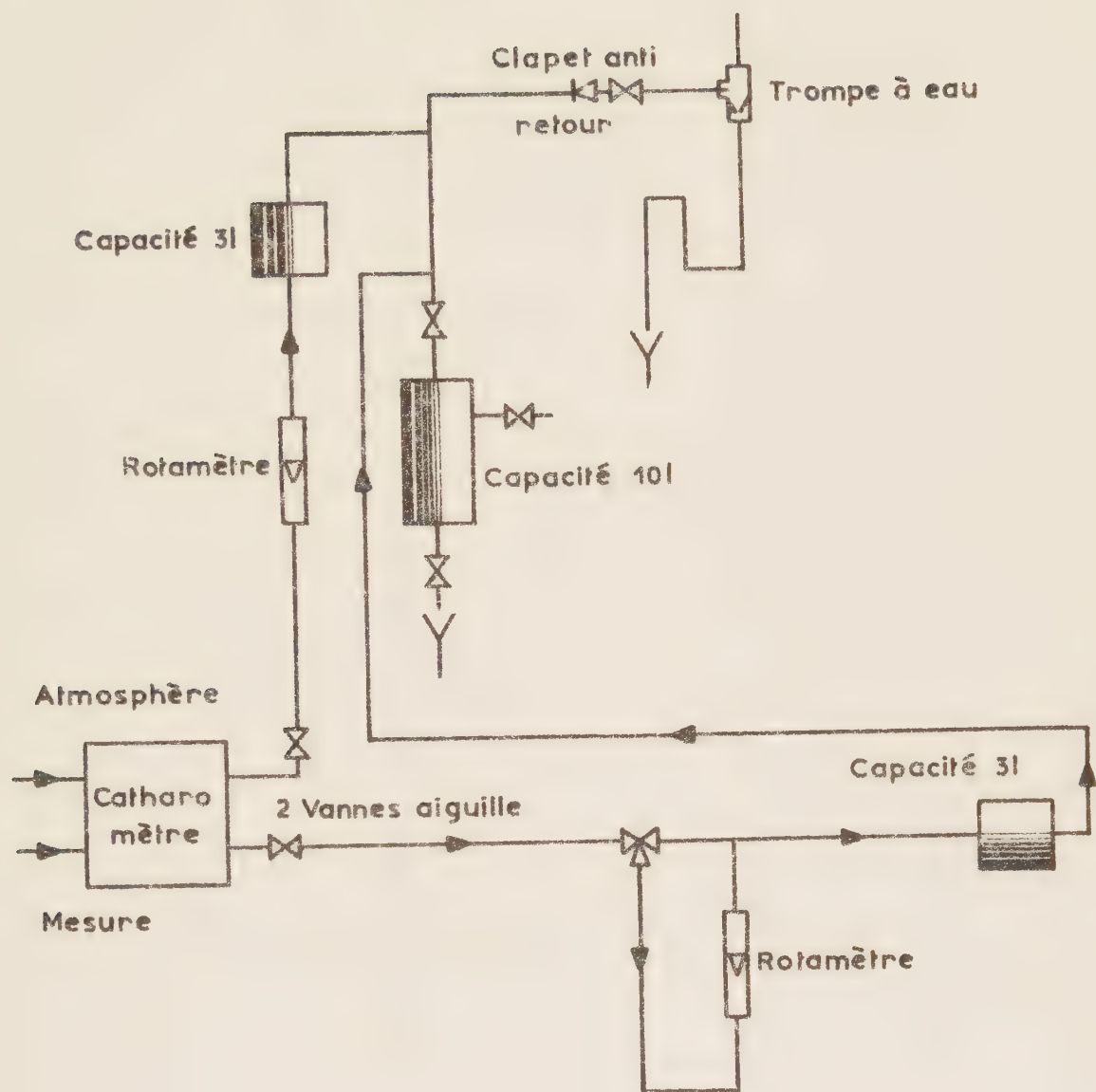
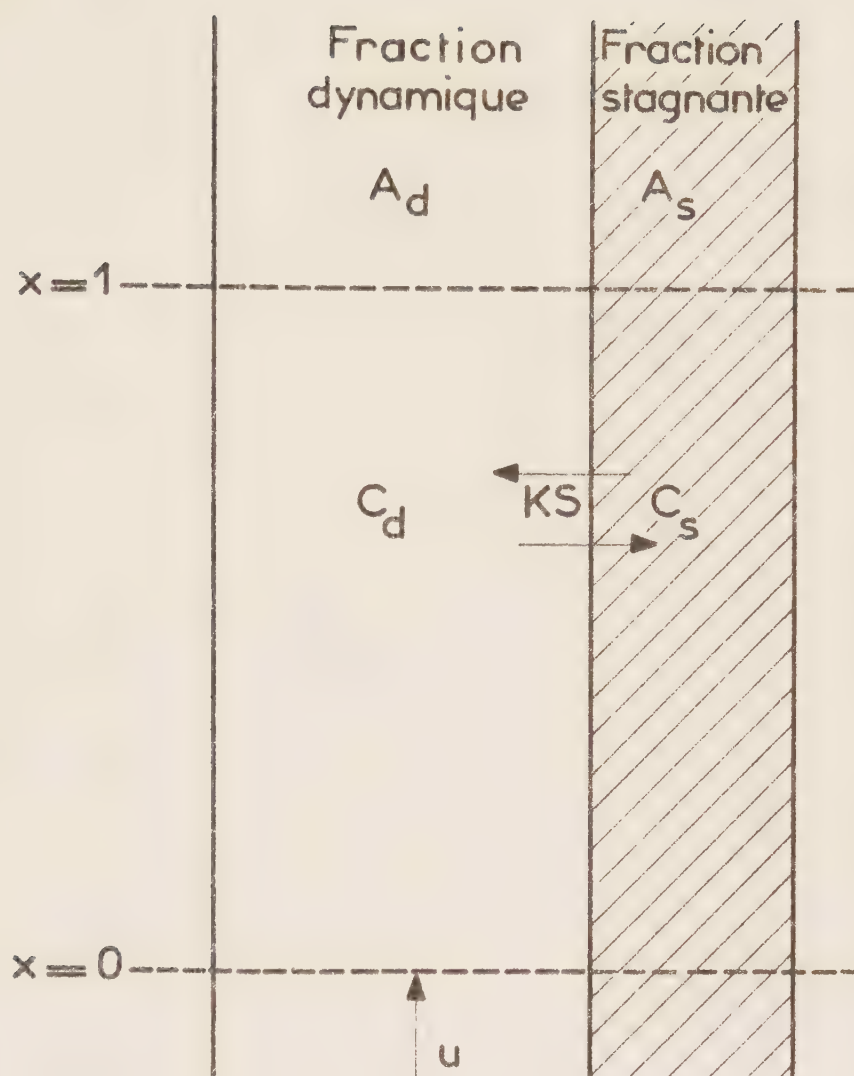


Fig. III-4: Annexes du PRELEVEMENT.



MODELE P.D.E.

Figure IV-1

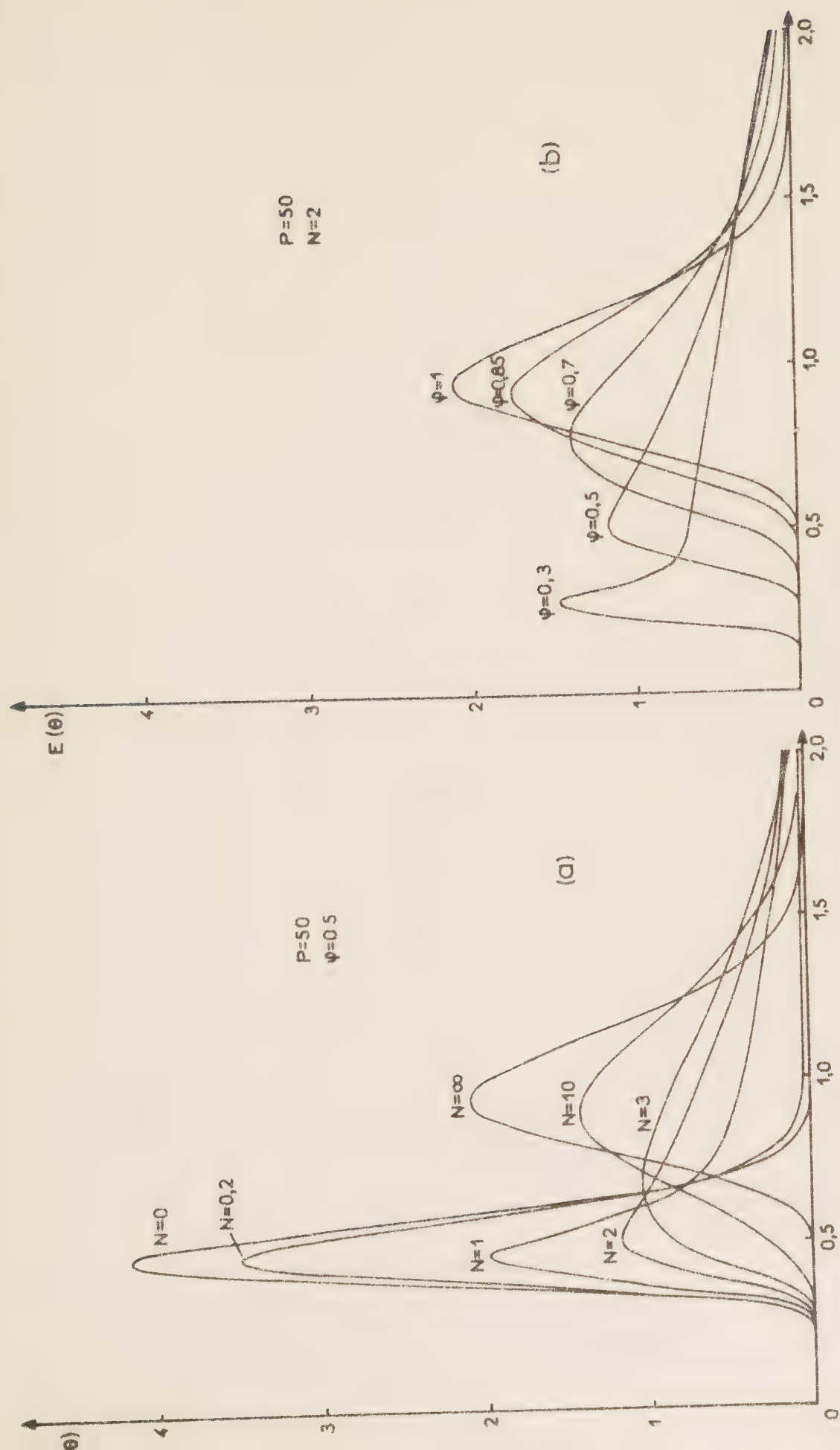


Fig. IV-2: COURBES THEORIQUES DU MODELE PDE.

(a): INFLUENCE DE N A ψ ET P CONSTANTS.

(b): INFLUENCE DE ψ A N ET P CONSTANTS.

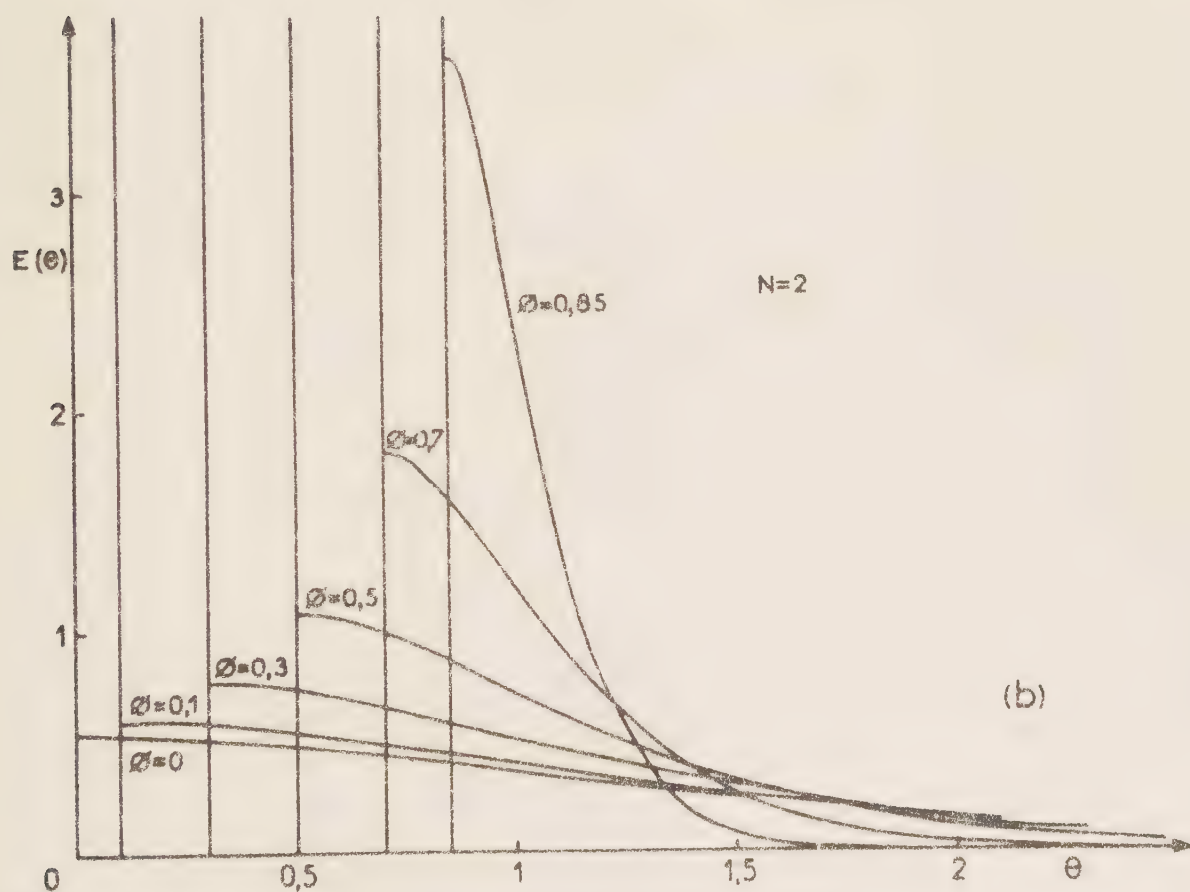
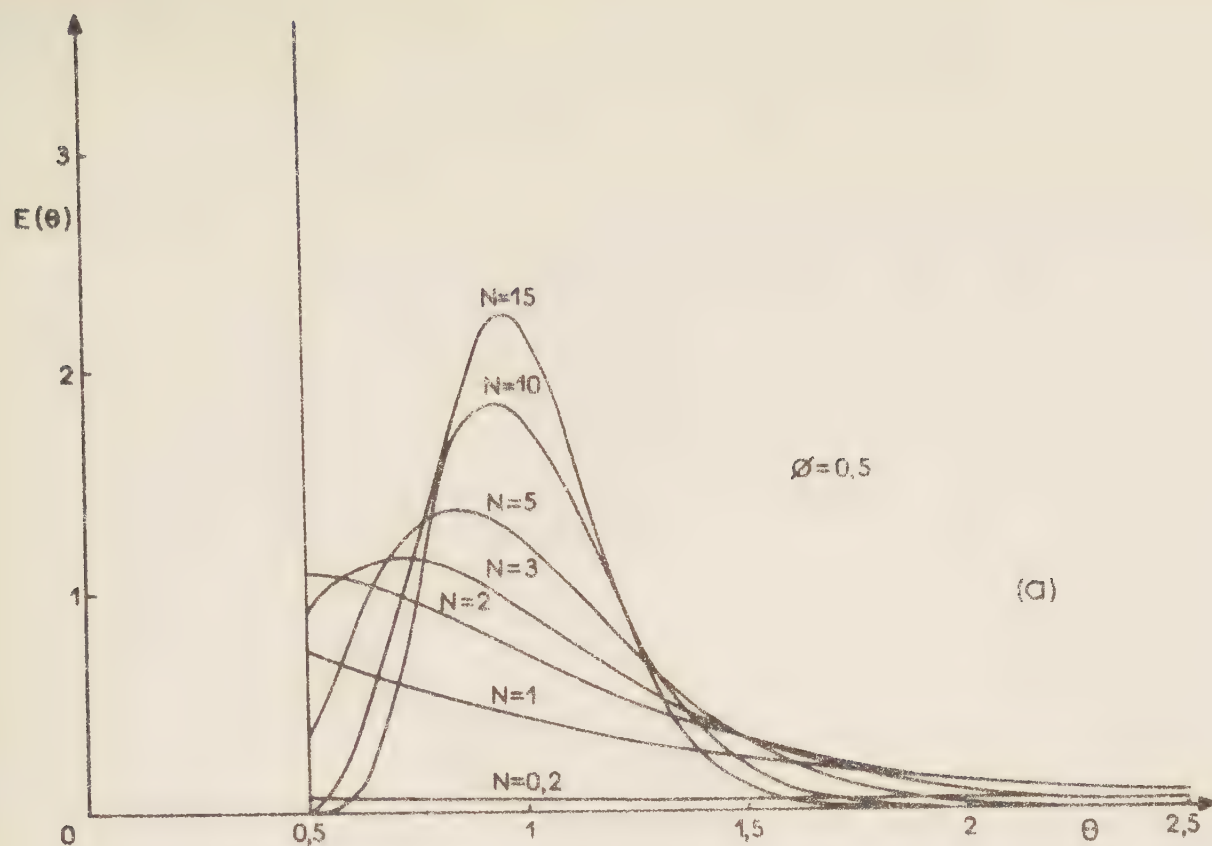
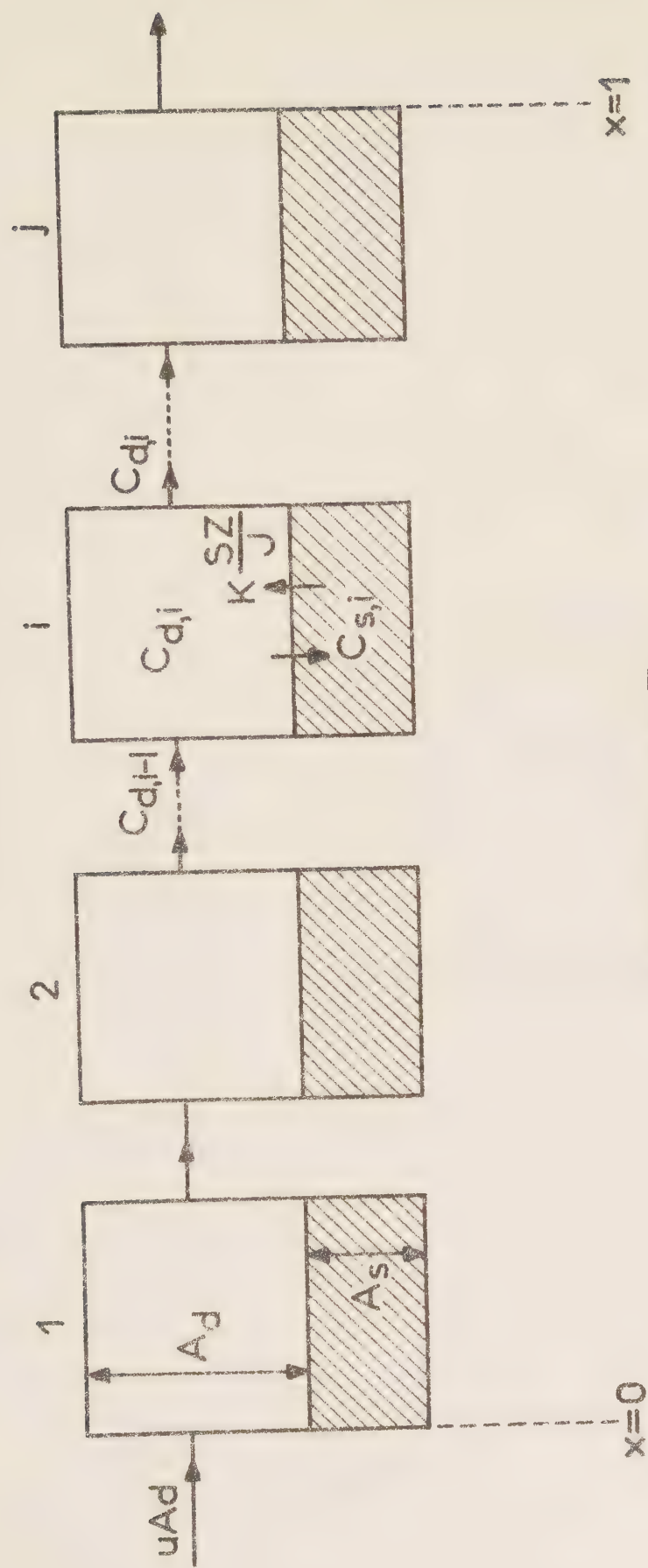


Fig. IV-3: COURBES THEORIQUES DU MODELE PE.

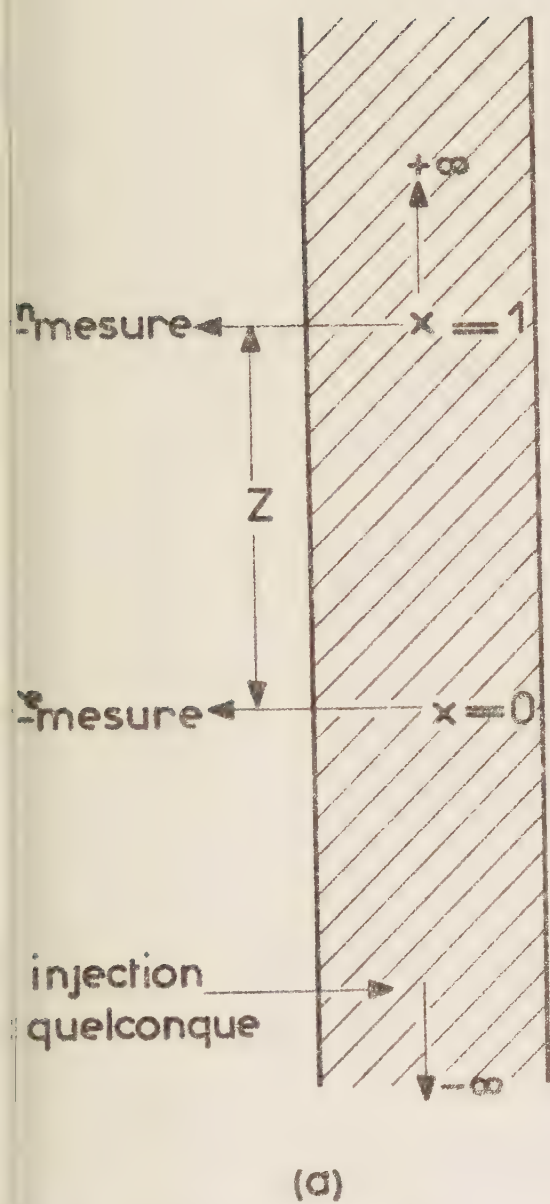
(a): INFLUENCE DE N A ϕ CONSTANT.

(b): INFLUENCE DE ϕ A N CONSTANT.

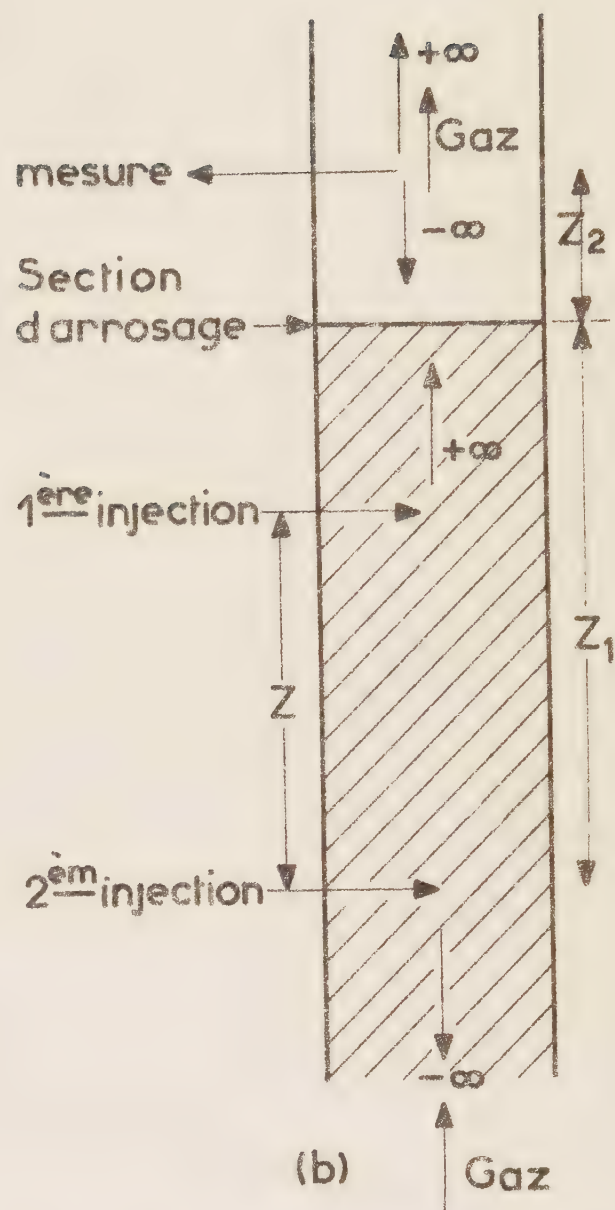


Modèle M.C.E.

Fig. IV-4



METHODE DE ARIS -



- METHODE DES 2 INJECTIONS -

Fig.IV-5

CONVOLUTION DU SIGNAL D'ENTREE

P	T
101,30	0,9962
82,16	0,9991
Courbe expérimentale	

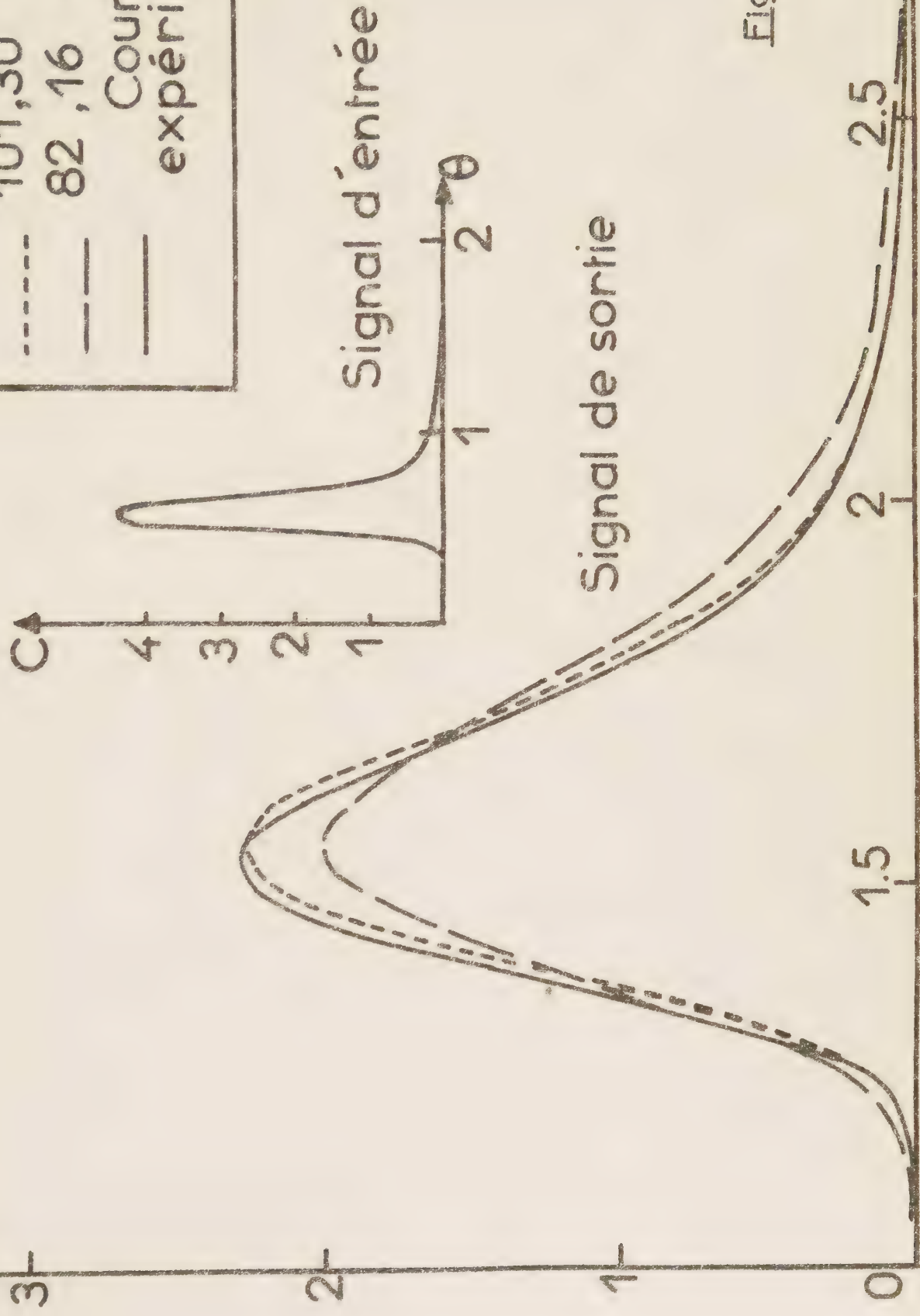
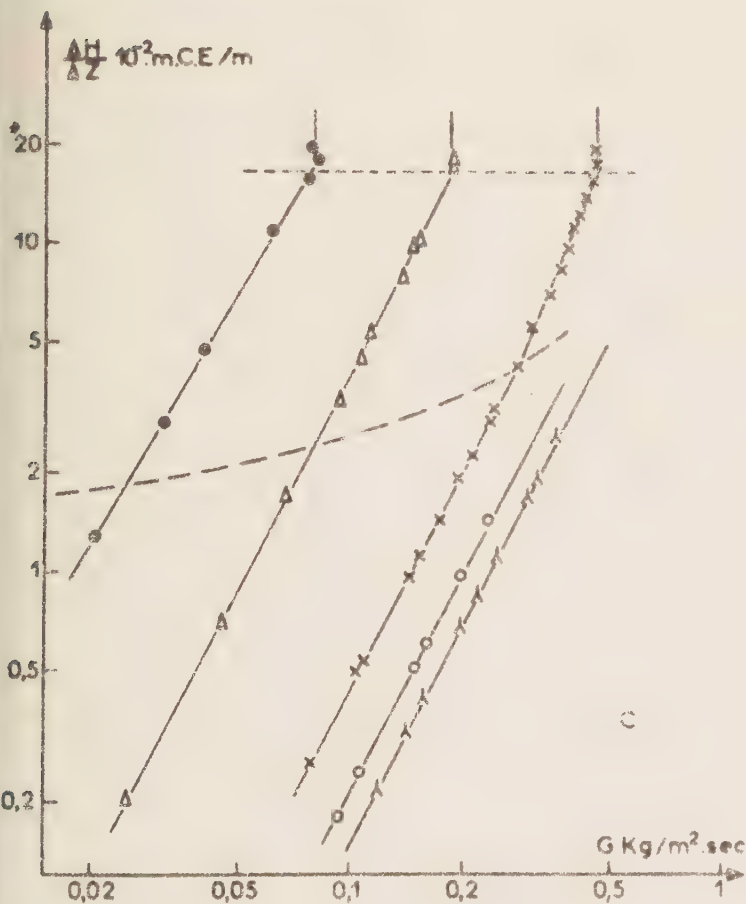
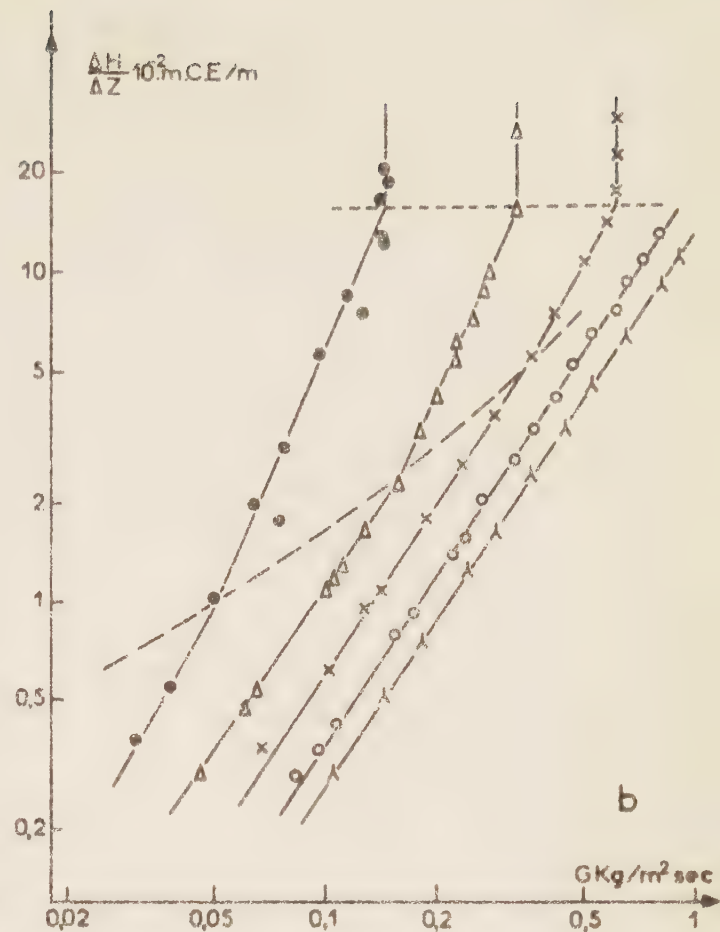
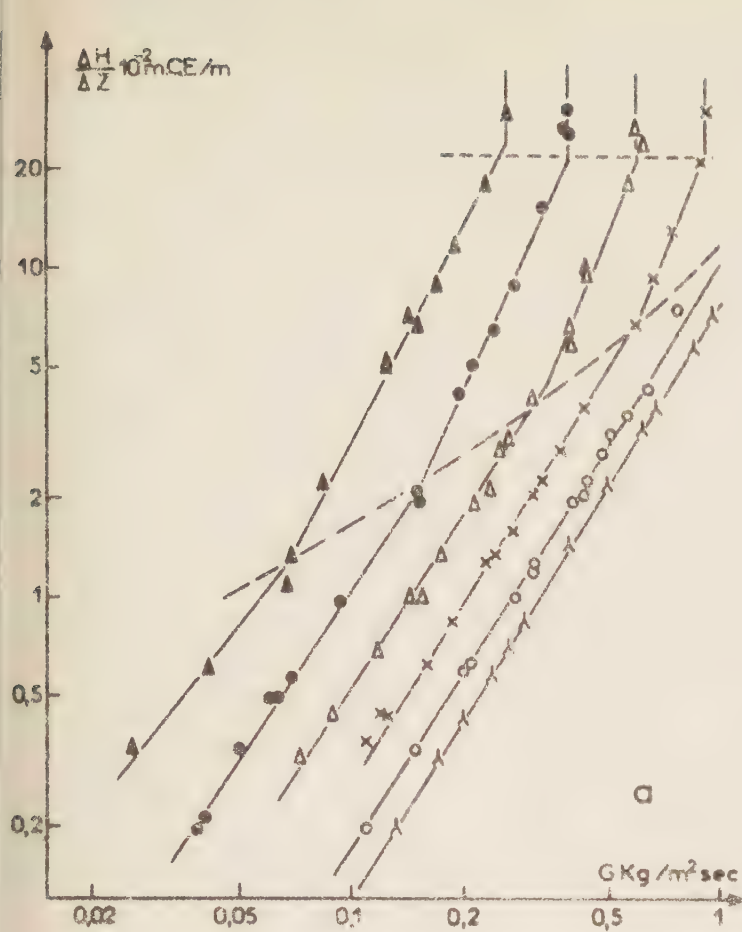


Fig.V,1



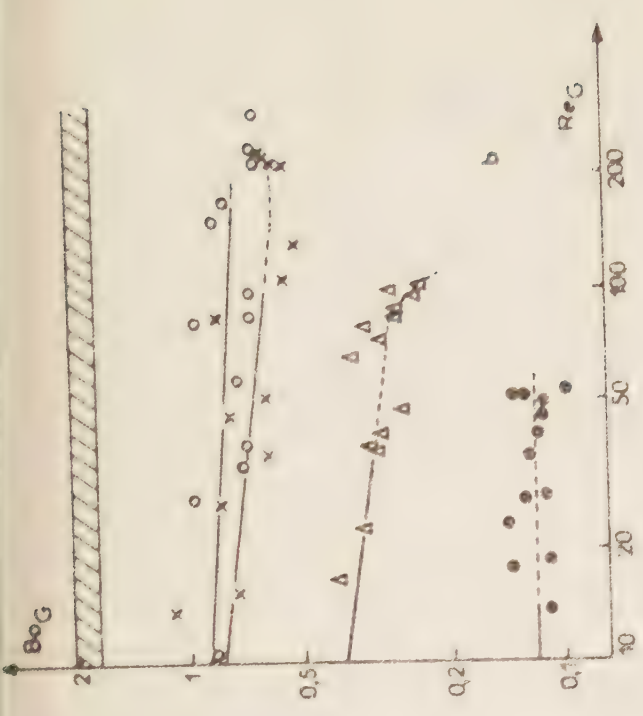
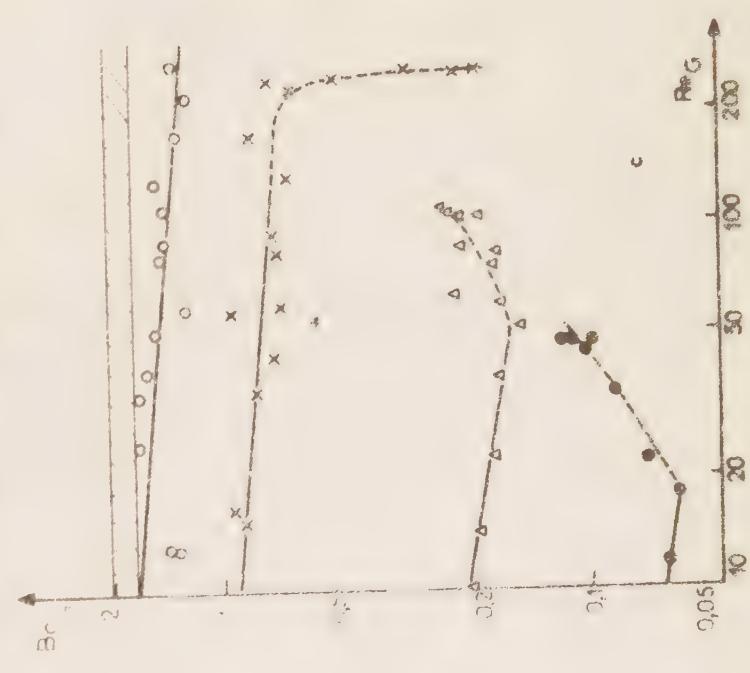
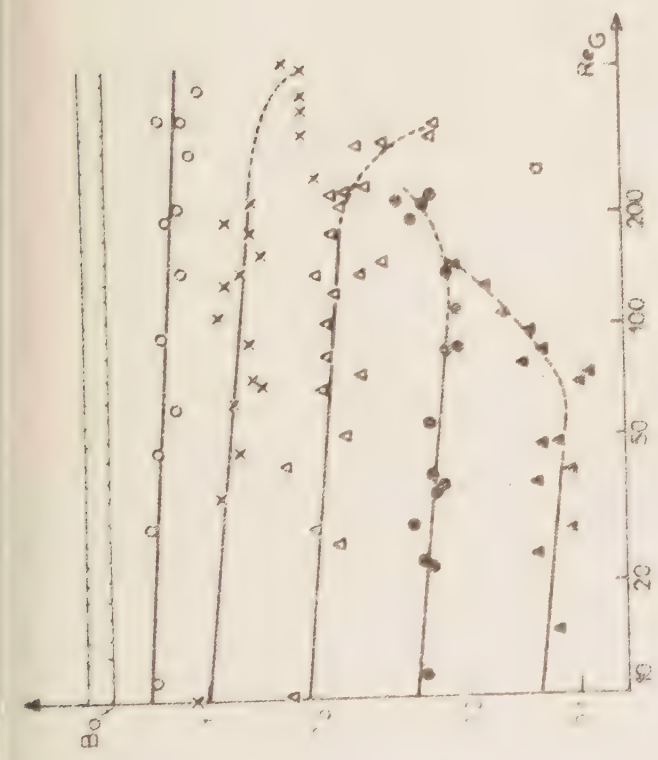
PERTES DE CHARGE

FIG.	GARNISSAGES
a	A.R. 10,3mm
b	A.R. 6,4mm
c	Billes 10mm

	Garnissage sec L Kg/m ² sec
o	0
x	2,3
Δ	6,5
•	10,5
▲	14,0

— — — — —	Points de charge
- - - - -	Points d'engorgement

Fig. VI-1



INFLUENCE DU DEBIT GAZEUX SUR LA DISPERSION AXIALE: MODELE P D

FIG. GARNISSAGES

- a A.R. 10,3 mm
- b A.R. 6,4 mm
- c Billes 10 mm

	GARNISSAGE SEC
	L: Kg/m ² sec
	0
	2,3
	6,5
	10,5
	140

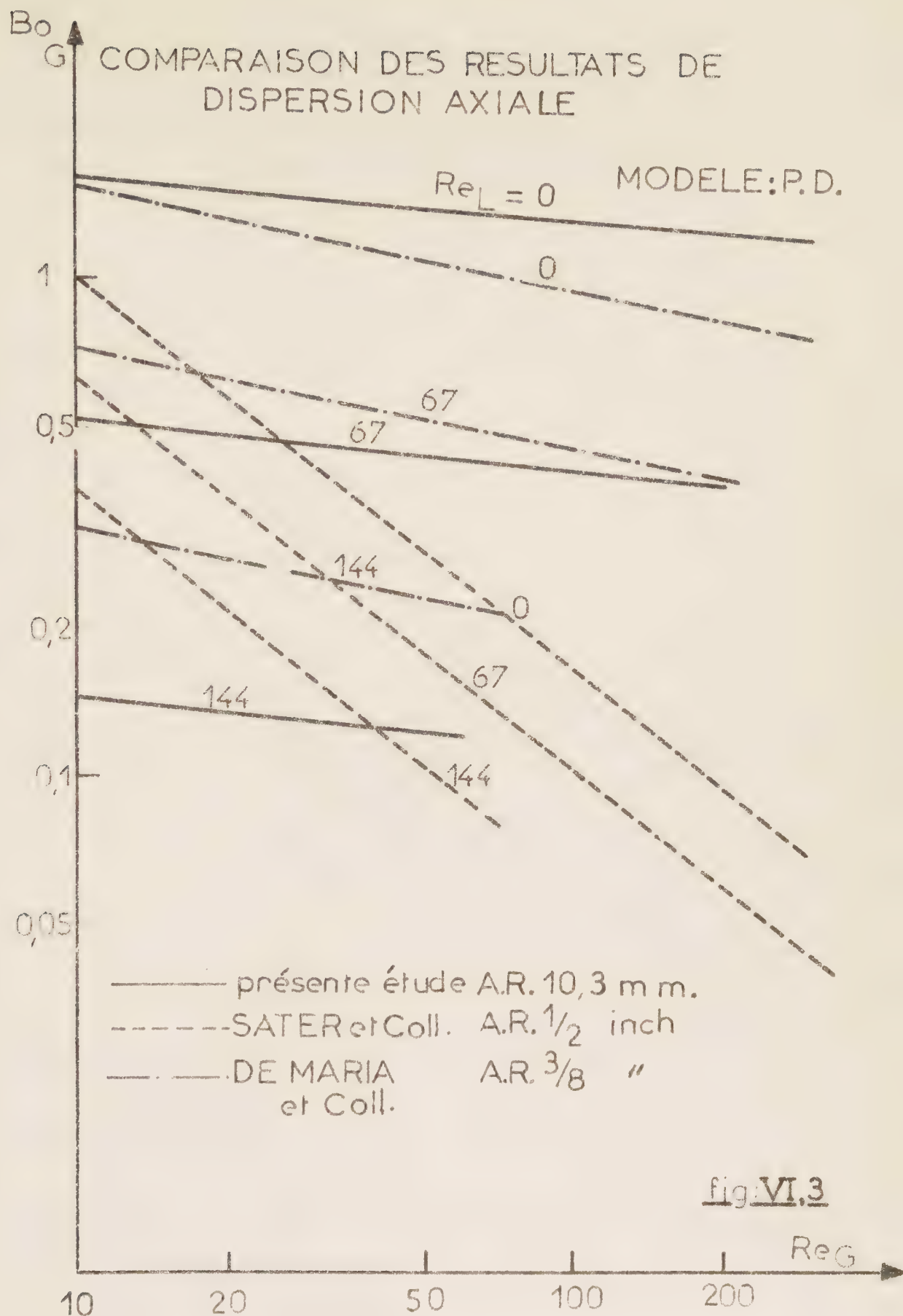


fig:VI.3

RESULTATS DE DISPERSION AXIALE
MODELE P. D. (Méthode des écarts-types)

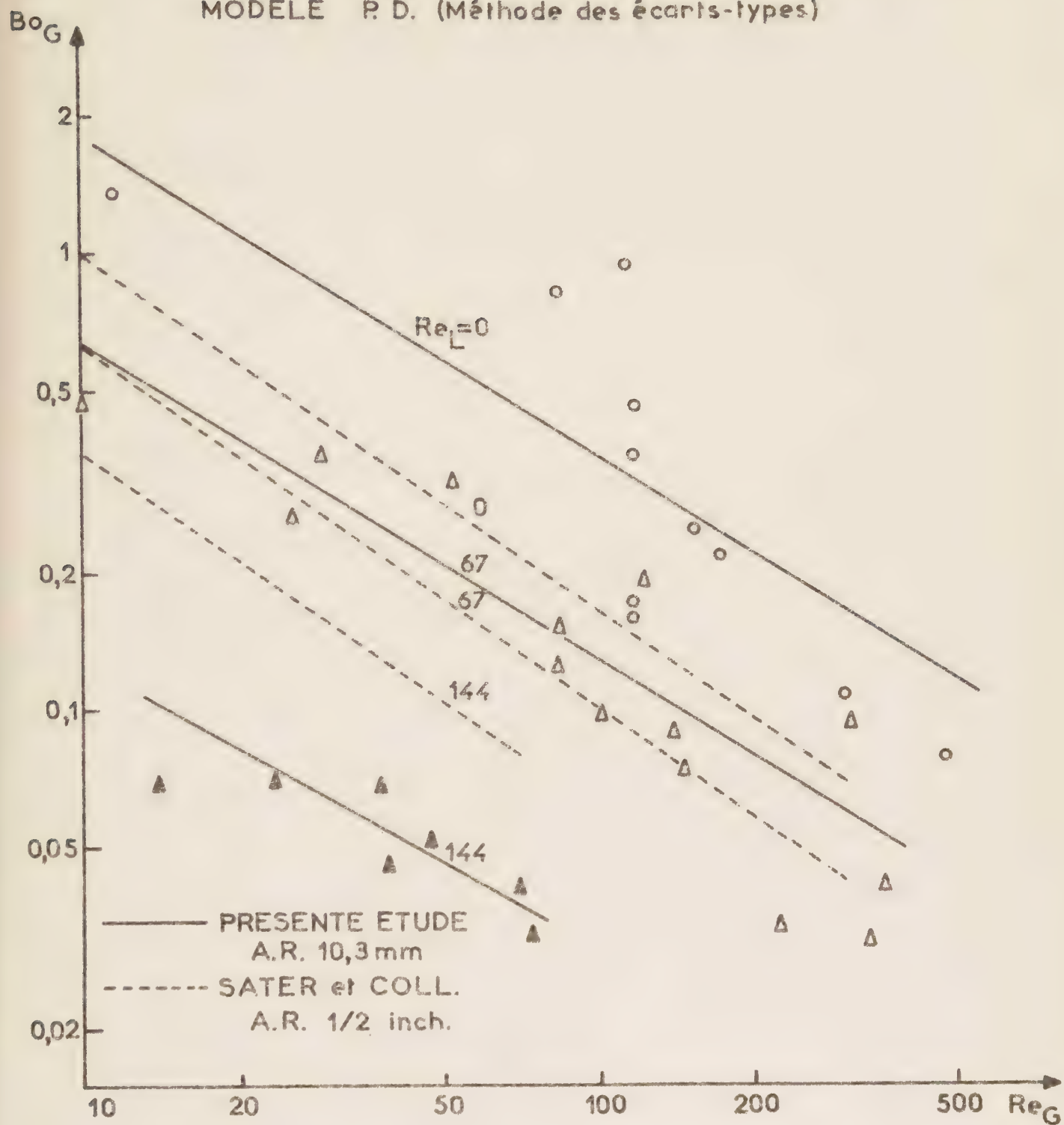
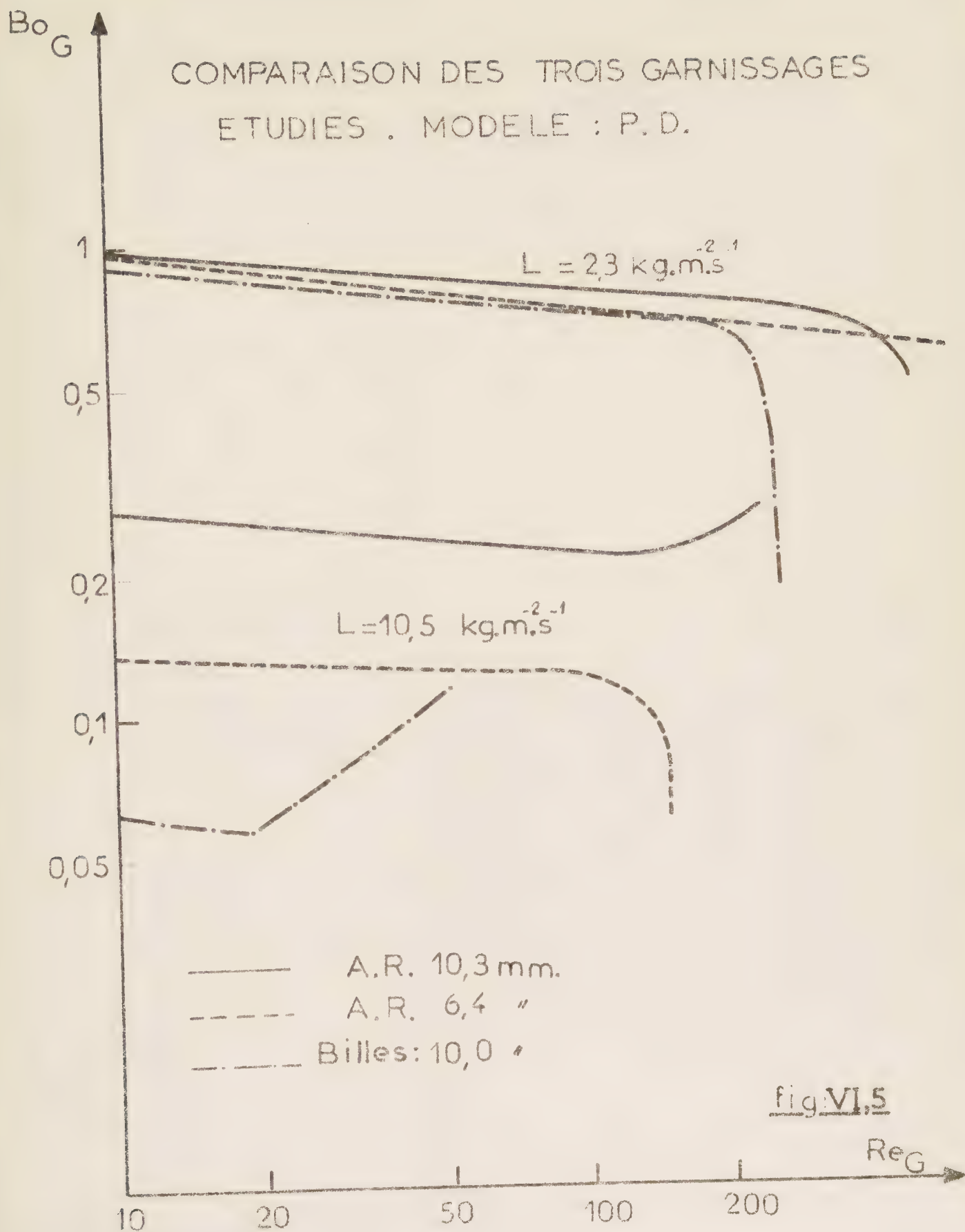


Fig. VI,4



DISPERSION AXIALE DANS LA PHASE GAZEUSE

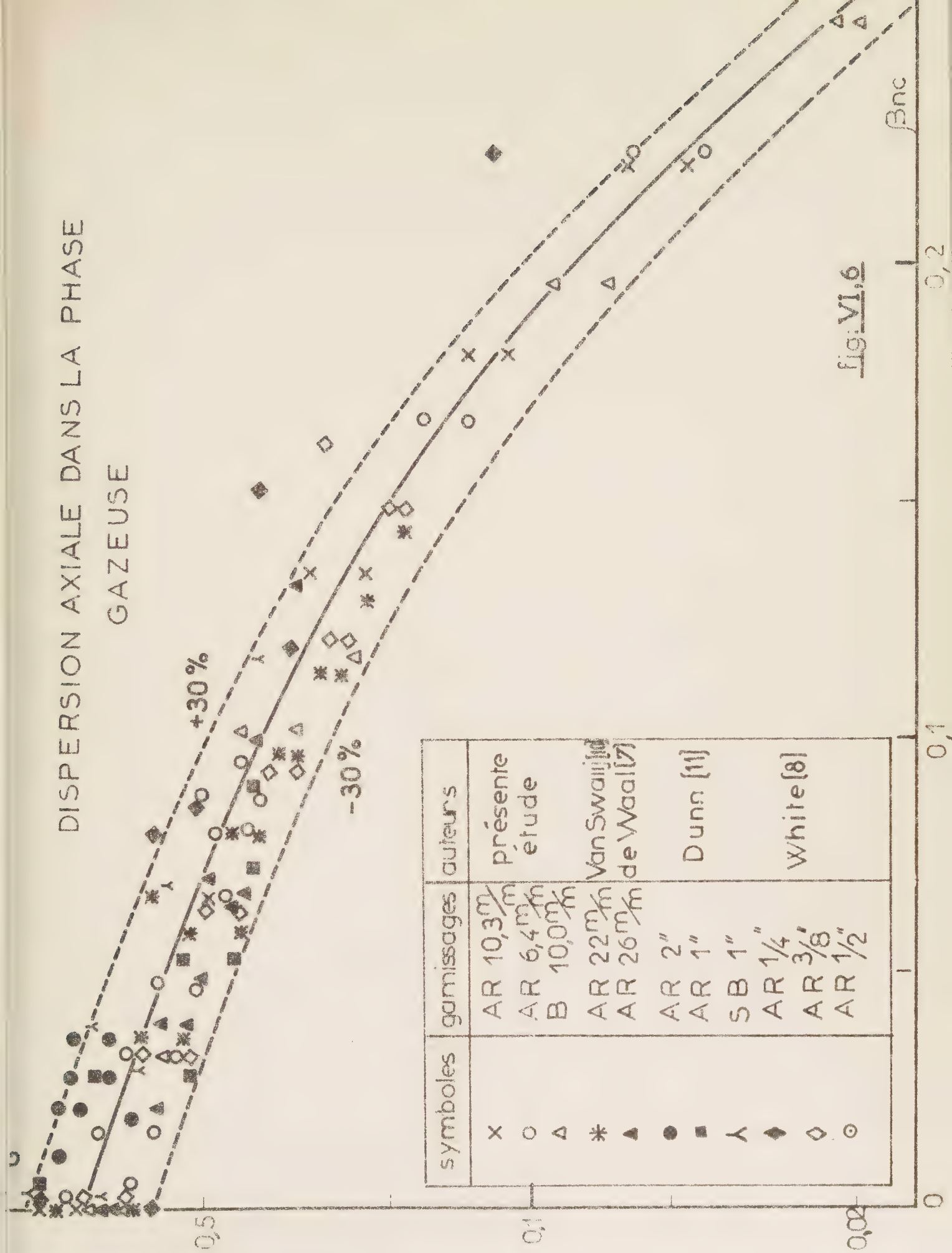
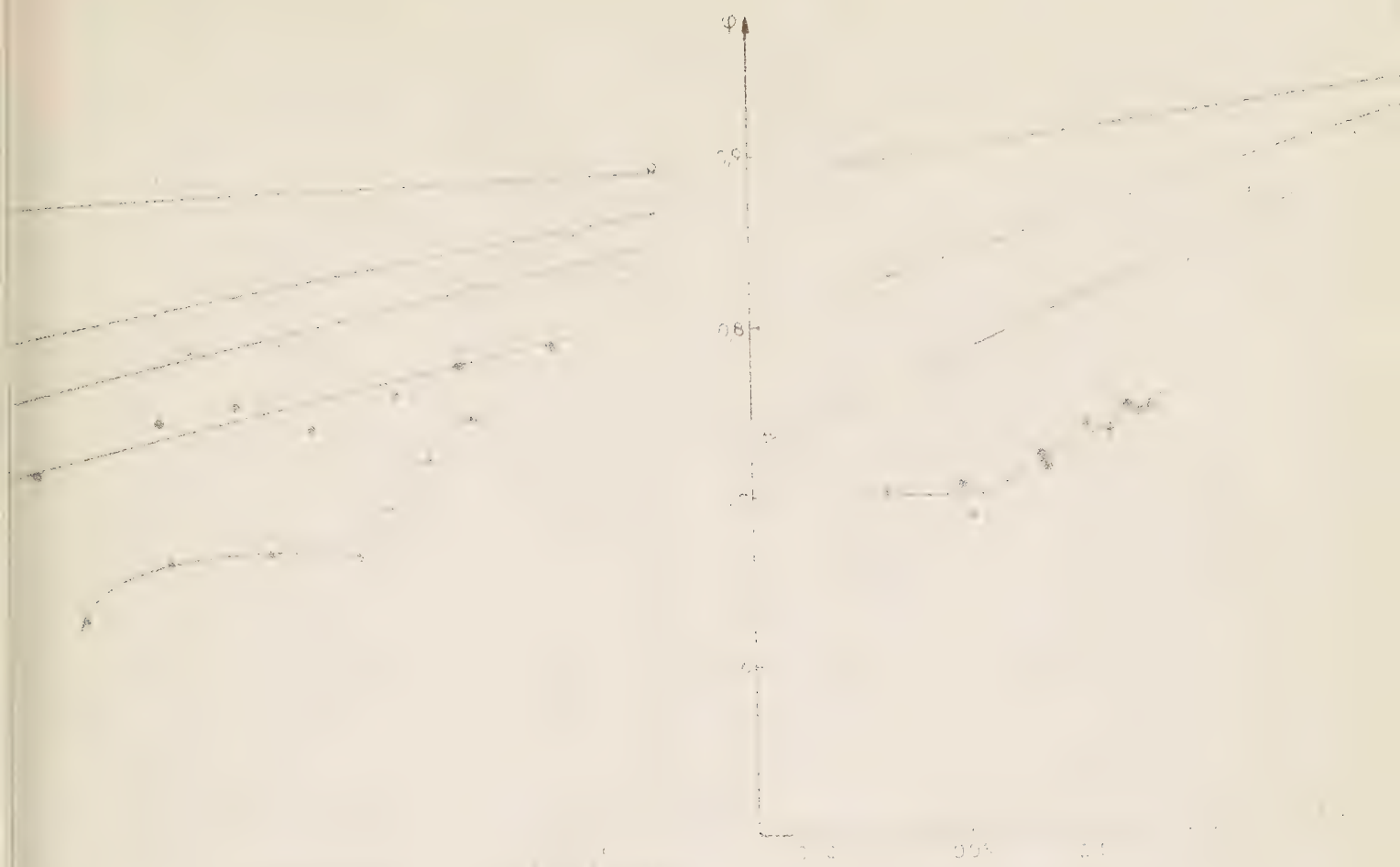


fig. VI.6

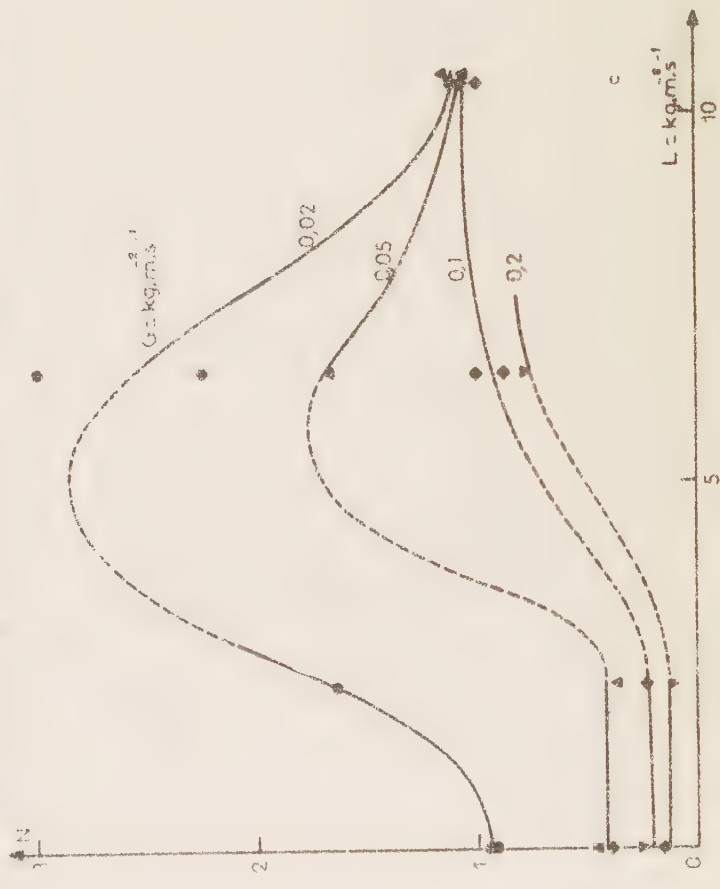
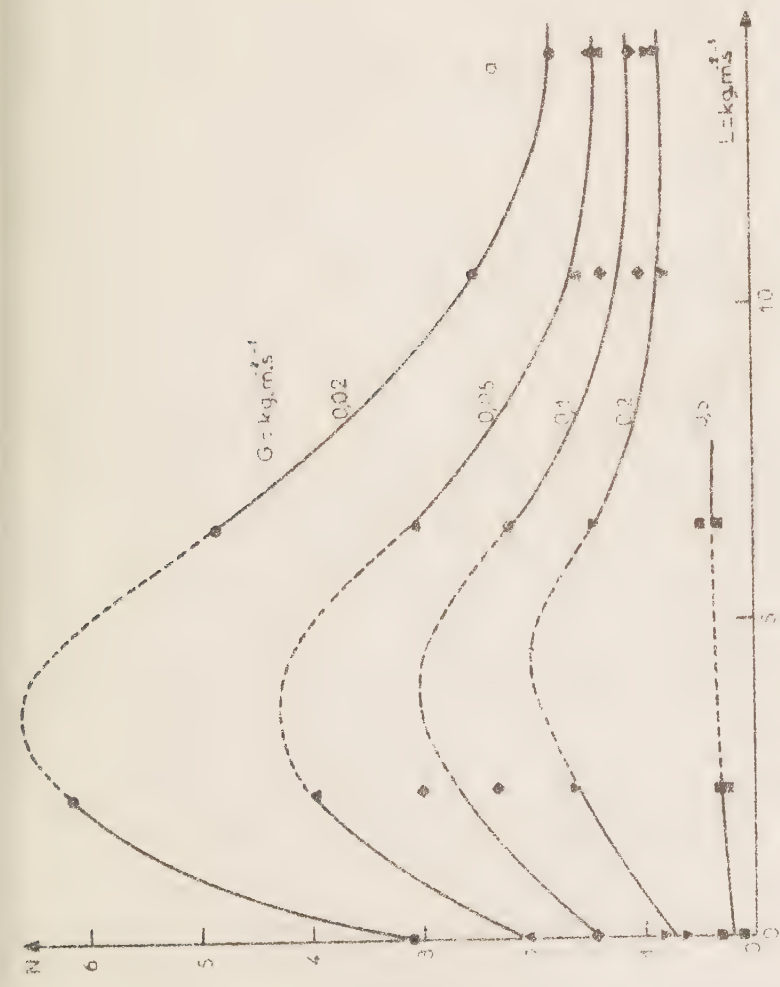
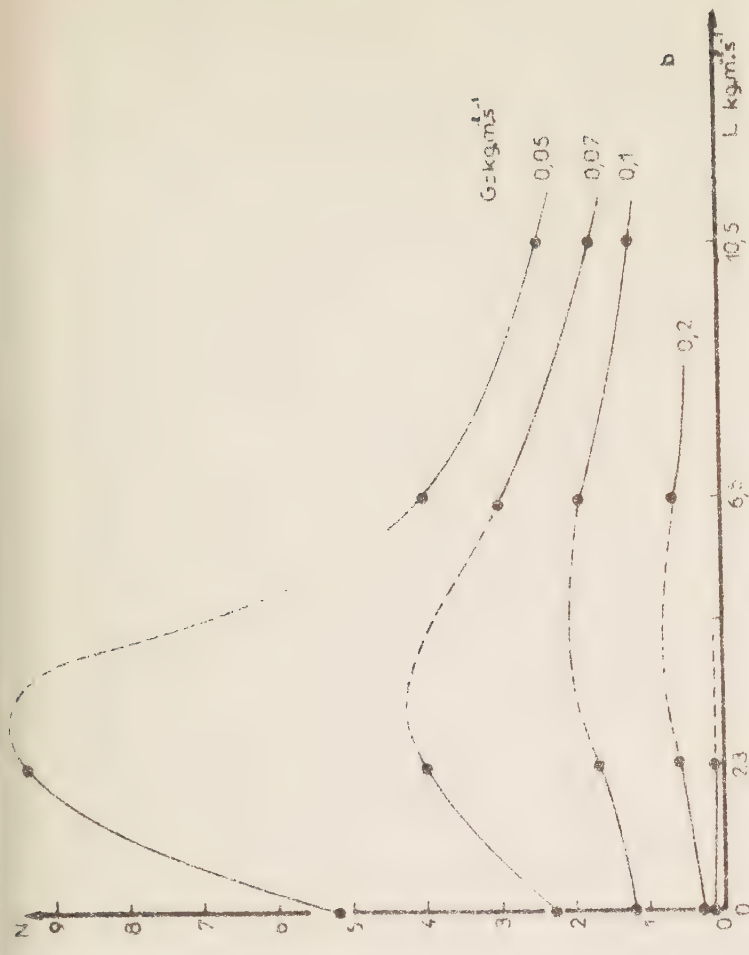


FRACTION MOBILE DE GAZ: ϕ
MODELE: P.E.

FIG	GARNISSAGES
B:c	A.R. 10,3 mm
B:b	A.R. 6,4 mm
B:c	Billes 10 mm
	L.C. KO. m. S.

a
b
c

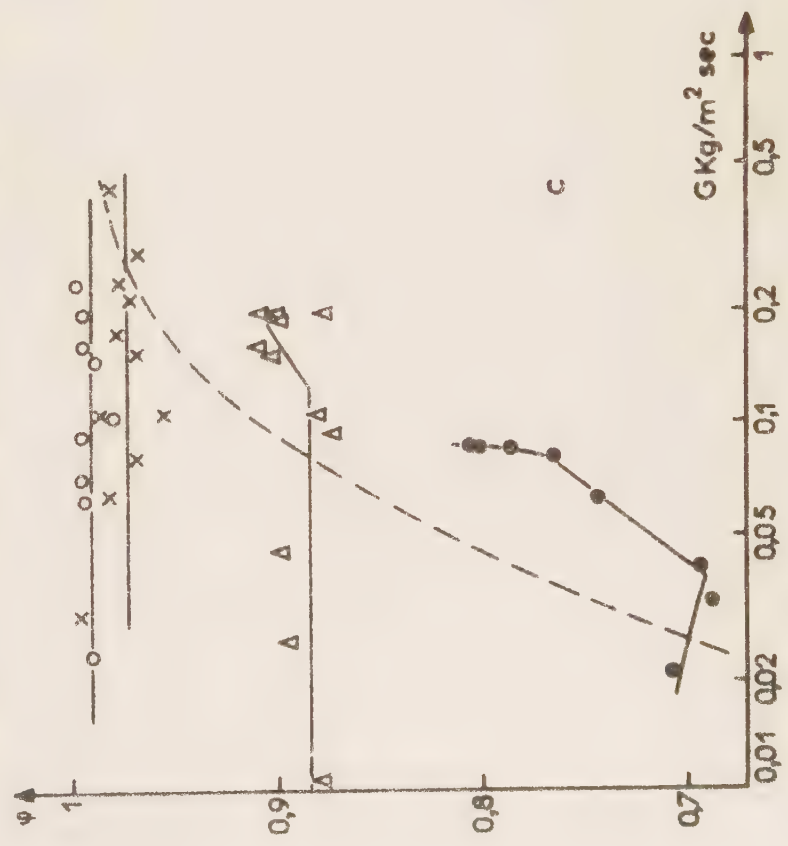
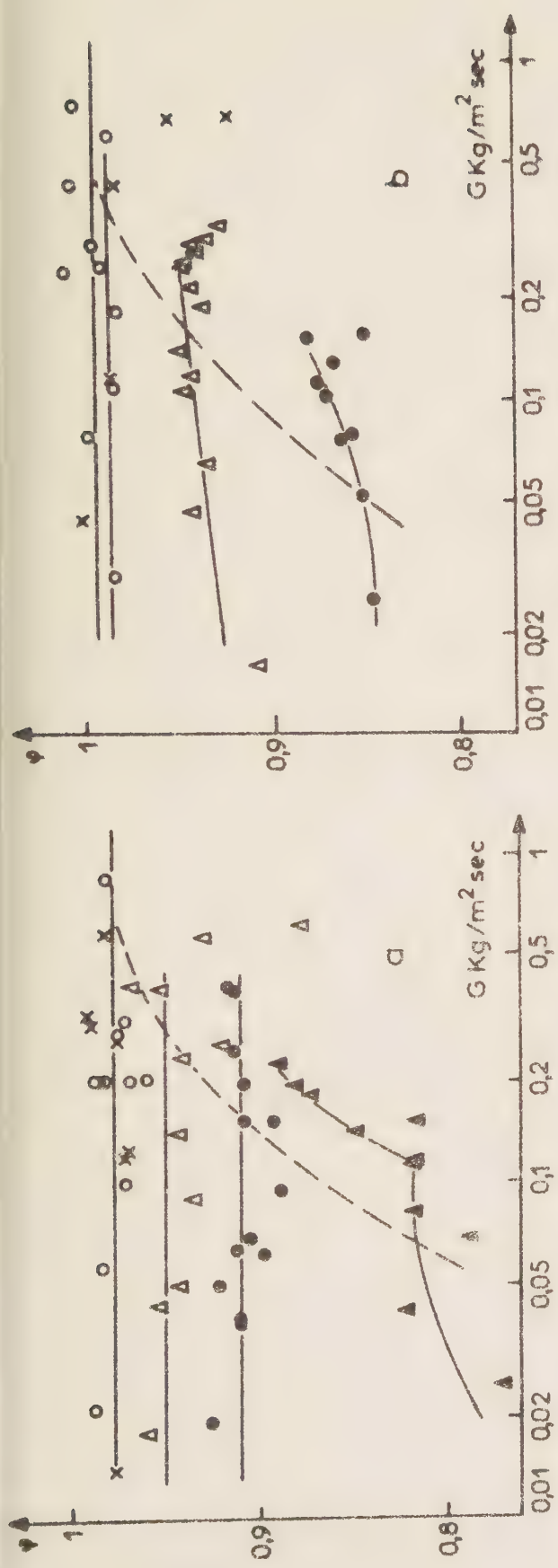
Fig VI,7



TRANSFERT DE MATIERE ENTRE LES FRACTIONS
MOBILE ET STAGNANTE DU GAZ
MODELE: P.E.

FIG: GARNISSAGES:
9: a A.R: 10,3 mm
9: b A.R: 6,4 mm
9: c B: 10 mm

Fig. VI.8

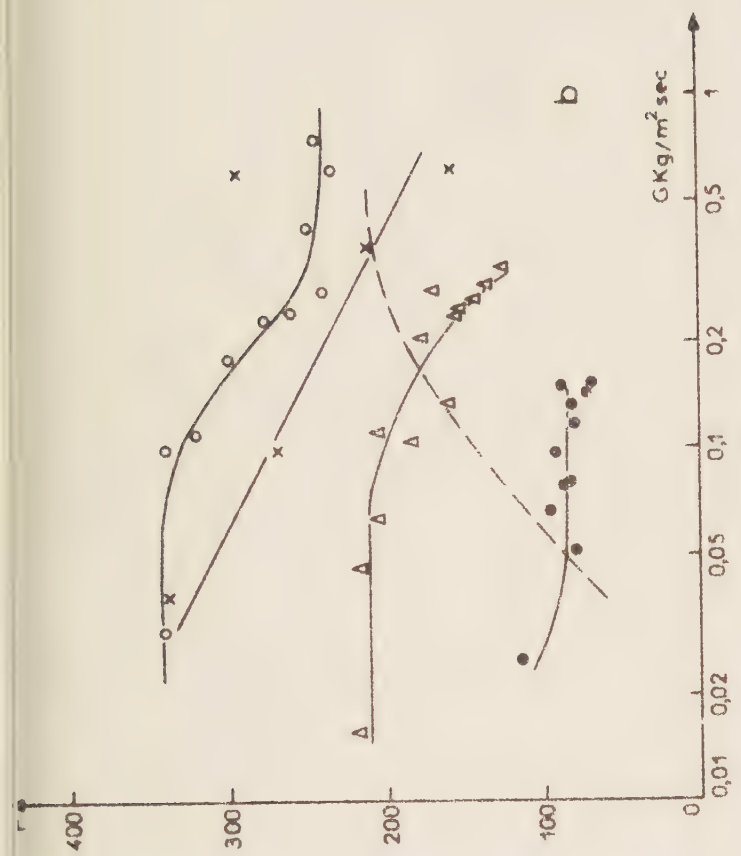
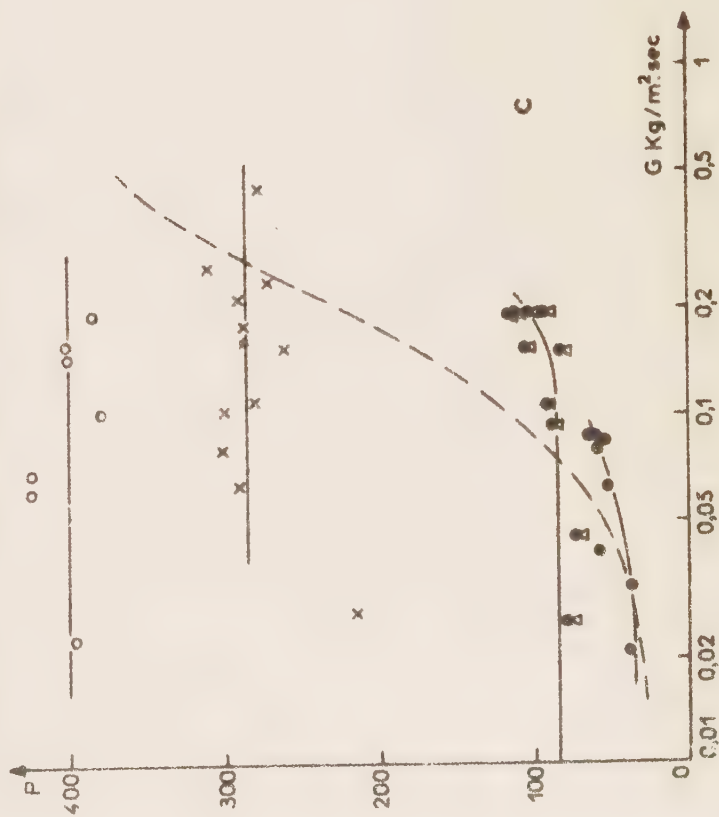
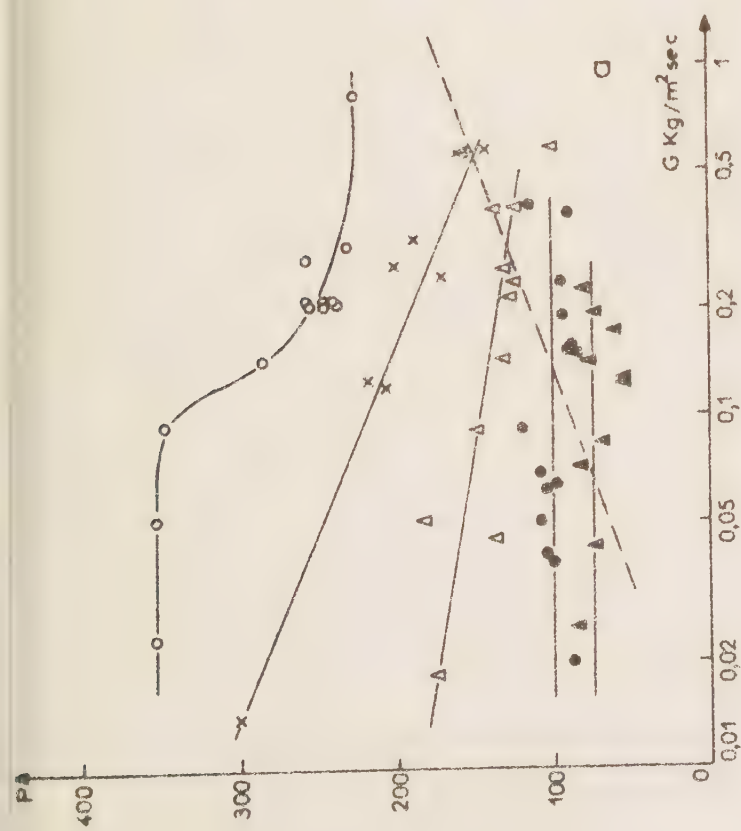


FRACTION MOBILE DE GAZ
MODELE P.D.E.
FIG. GARNISSAGES

a A.R. 10,3 mm
b A.R. 6,4 mm
c Billes 10 mm

	L Kg/m sec	Points de charge
o	0	
x	2,3	
Δ	6,5	
●	10,5	
▲	14,0	

Fig. VI.2



NOMBRE DE PECLET DE LA FRACTION MOBILE DU GAZ

MODELE PDE

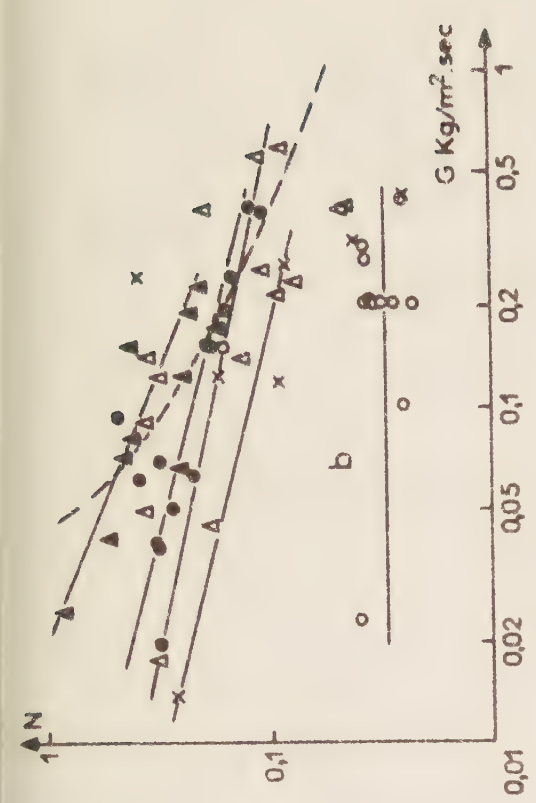
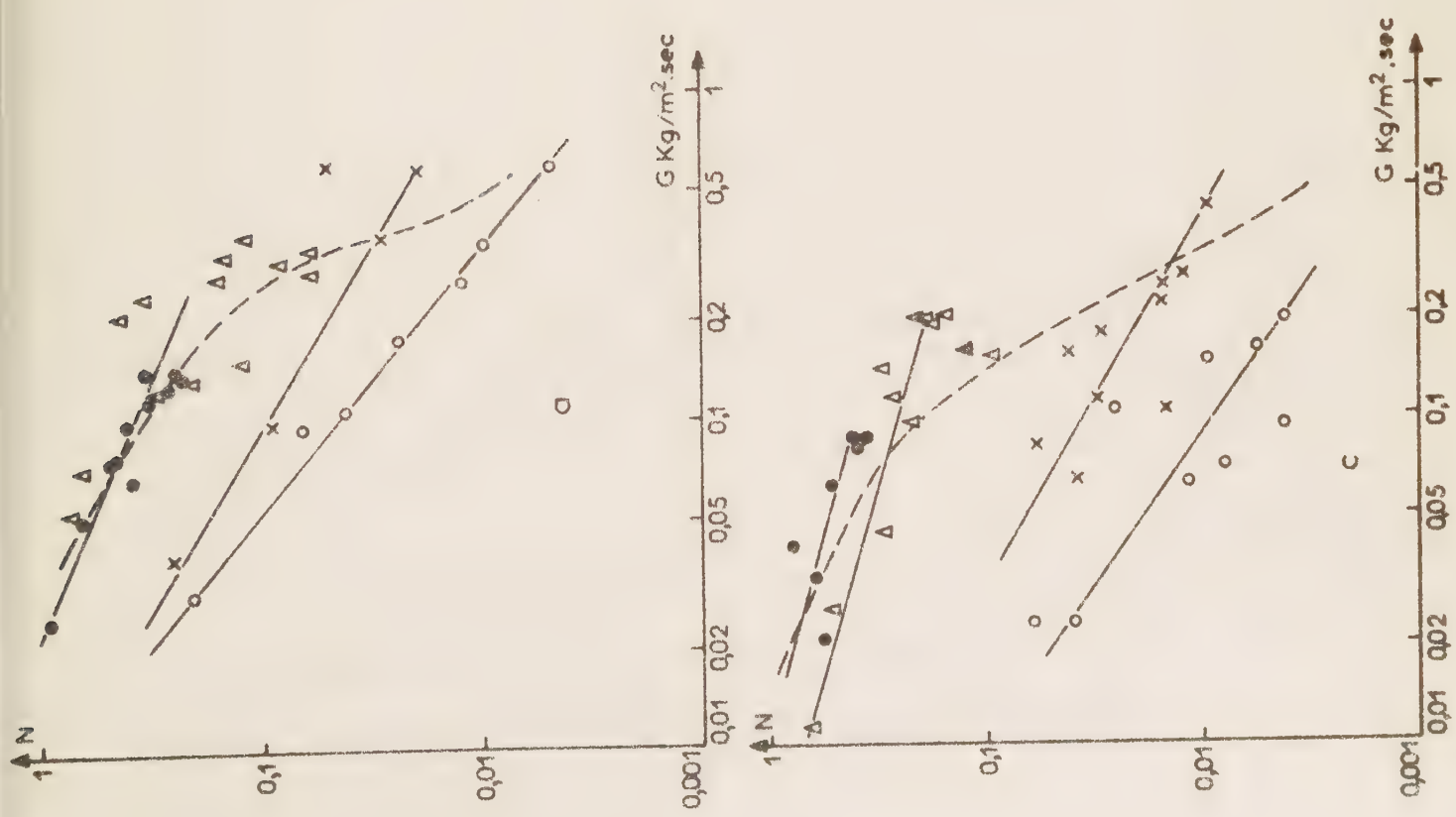
FIG.

GARNISSAGE
A.R. 10,3 mm
A.R. 6,4 mm
Billes 10 mm

L Kg/m² sec

0
2,3
6,5
10,5
14,0

Points de charge



TRANSFERT DE MATIERE ENTRE LES FRACTIONS
MOBILE ET STAGNANT DU GAZ

MODELE P.D.E.

FIG.

a
b
c

GARNISSAGE
A.R. 6,4 mm
A.R. 10,3 mm
Billes 10 mm

L Kg/m².sec

0
2,3
6,5
10,5
14,0

Points de charge

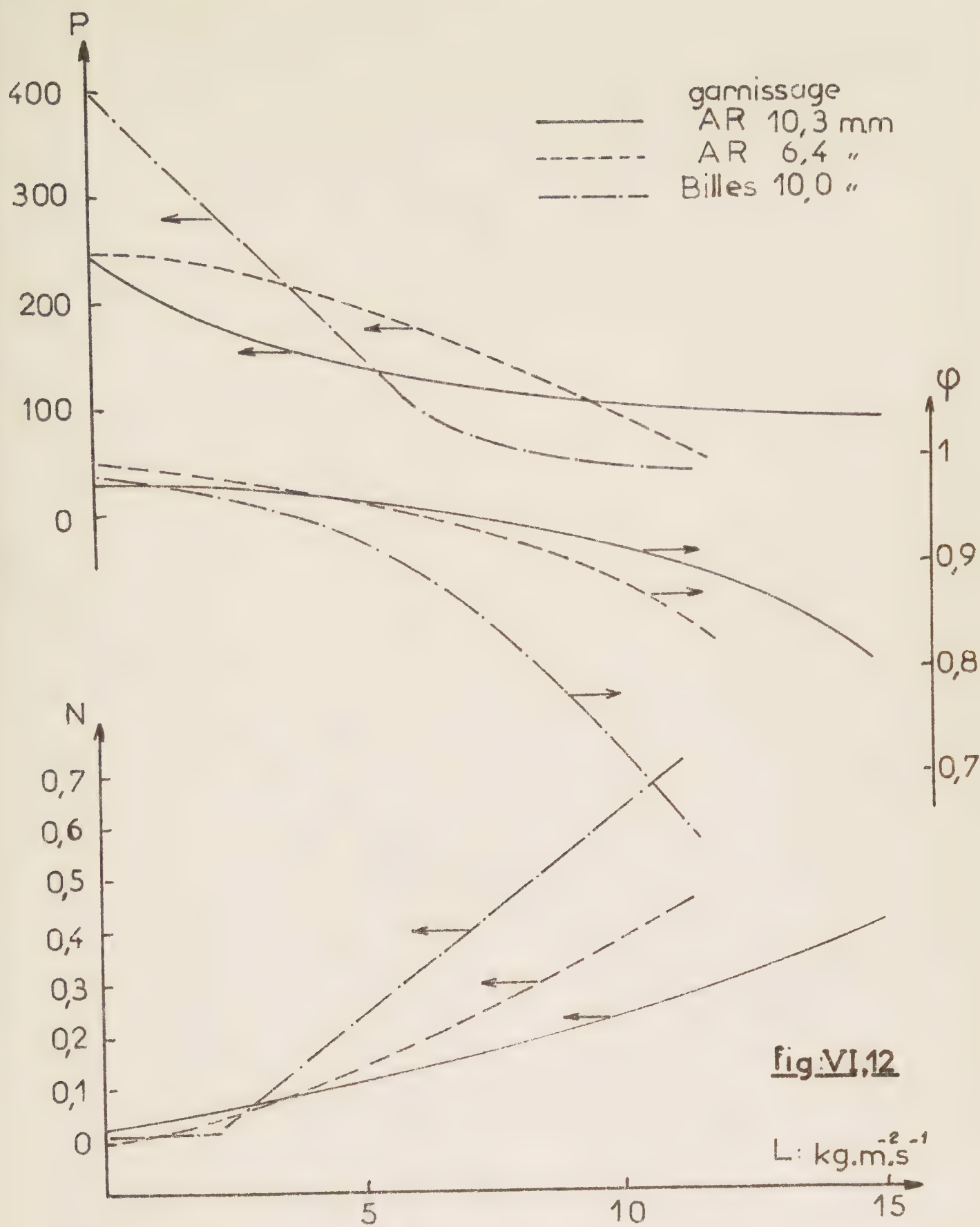
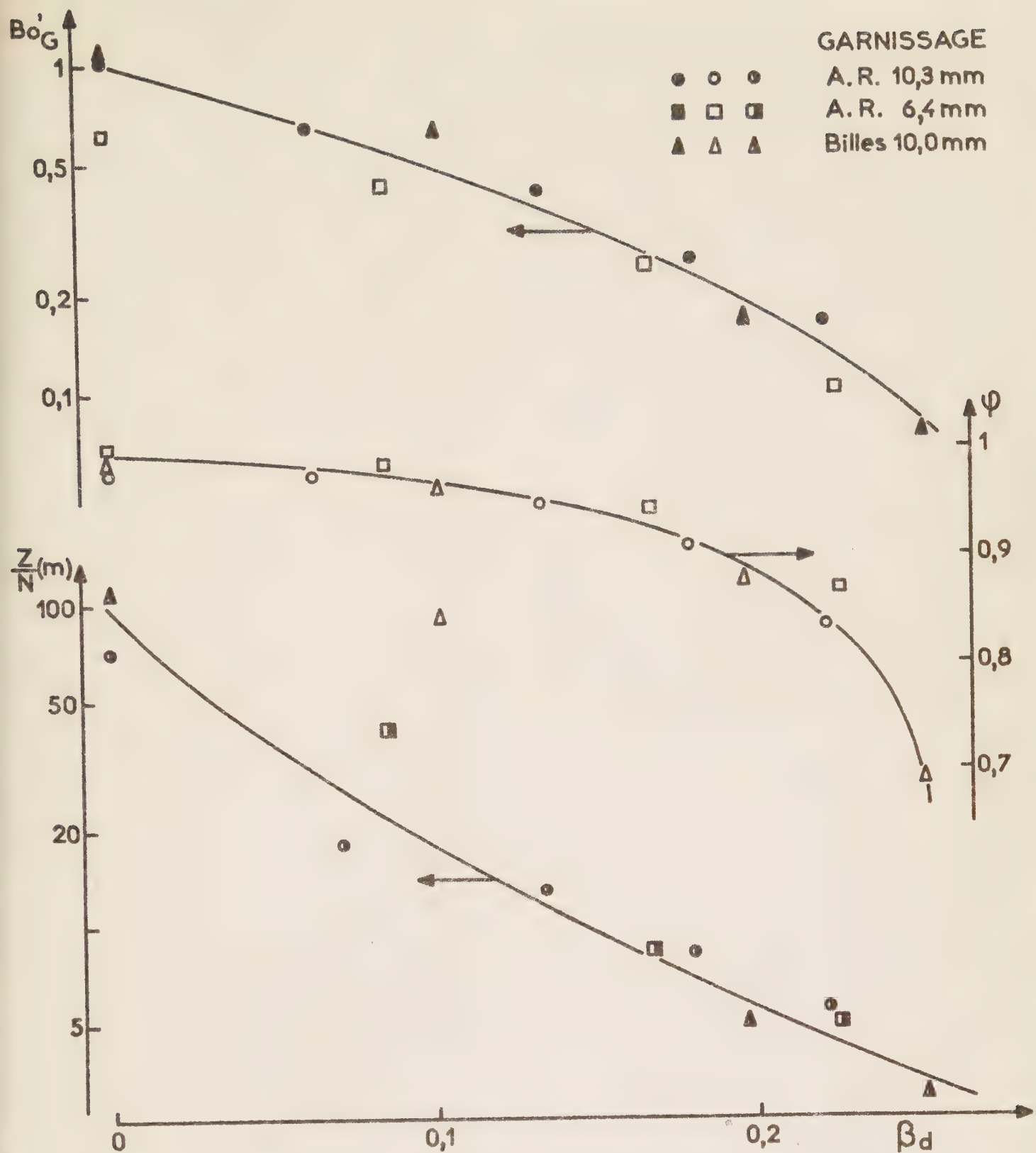


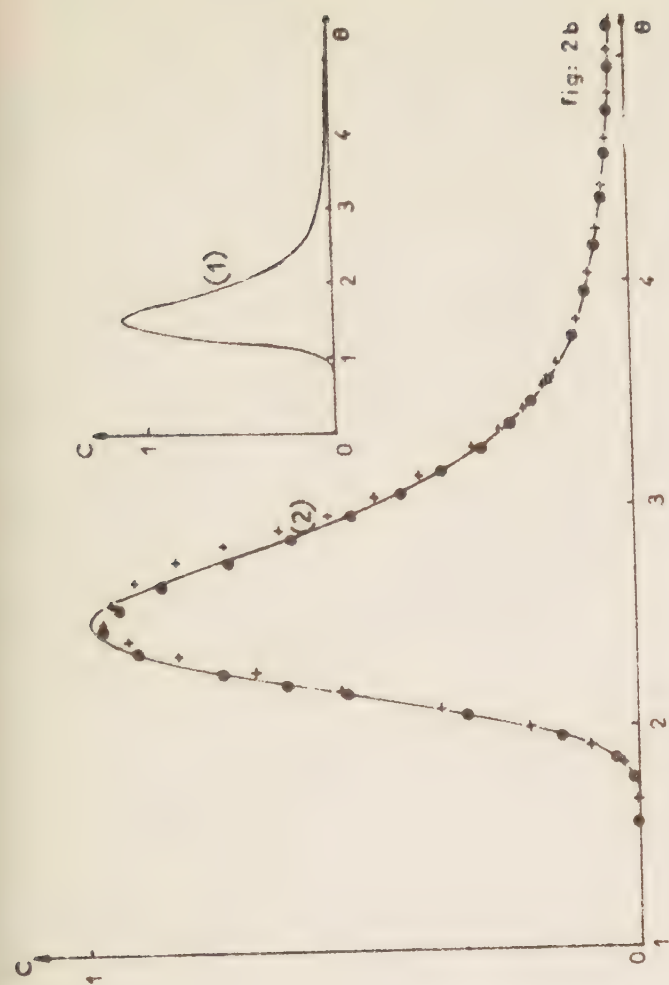
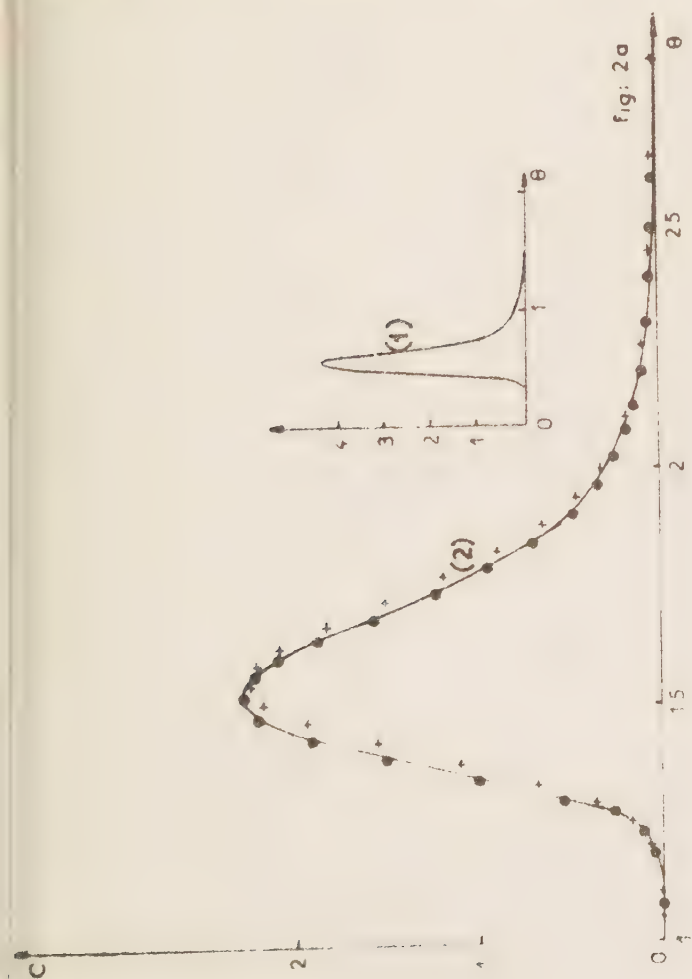
fig.VI,12

PARAMETRES: P, φ, N , DU MODELE: P.D.E.
 AU VOISINAGE DES POINTS DE CHARGE



PARAMETRES Bo'_G , ϕ , $\frac{Z}{N}$ DERIVES DU MODELE P.D.E.
 EN FONCTION DE β_d AU VOISINAGE DES POINTS DE CHARGE

Fig. VI,13



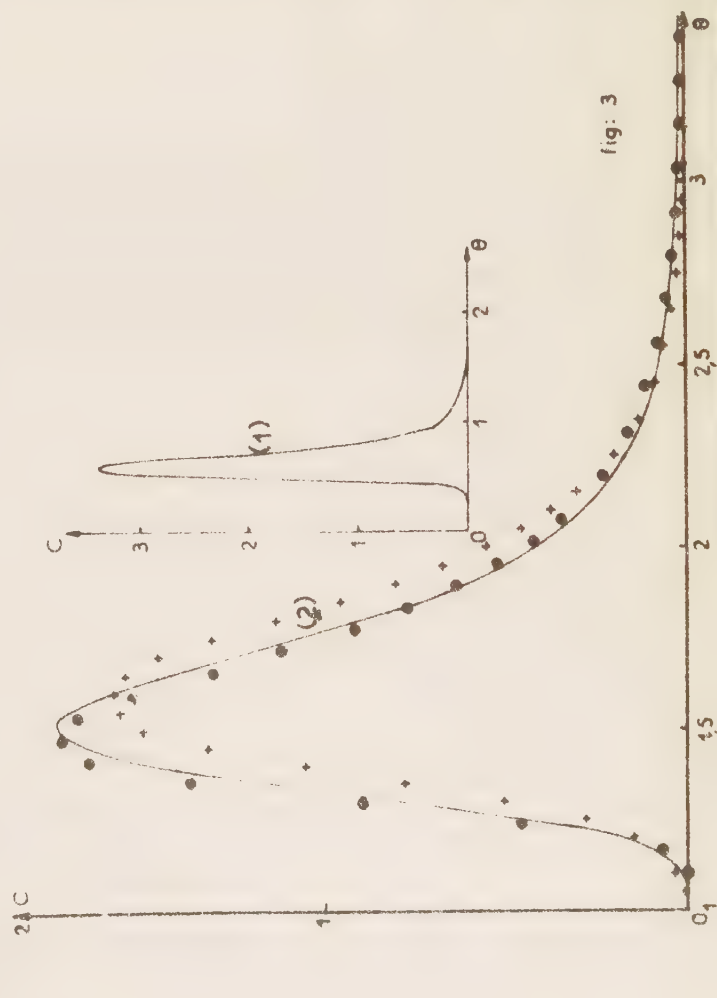
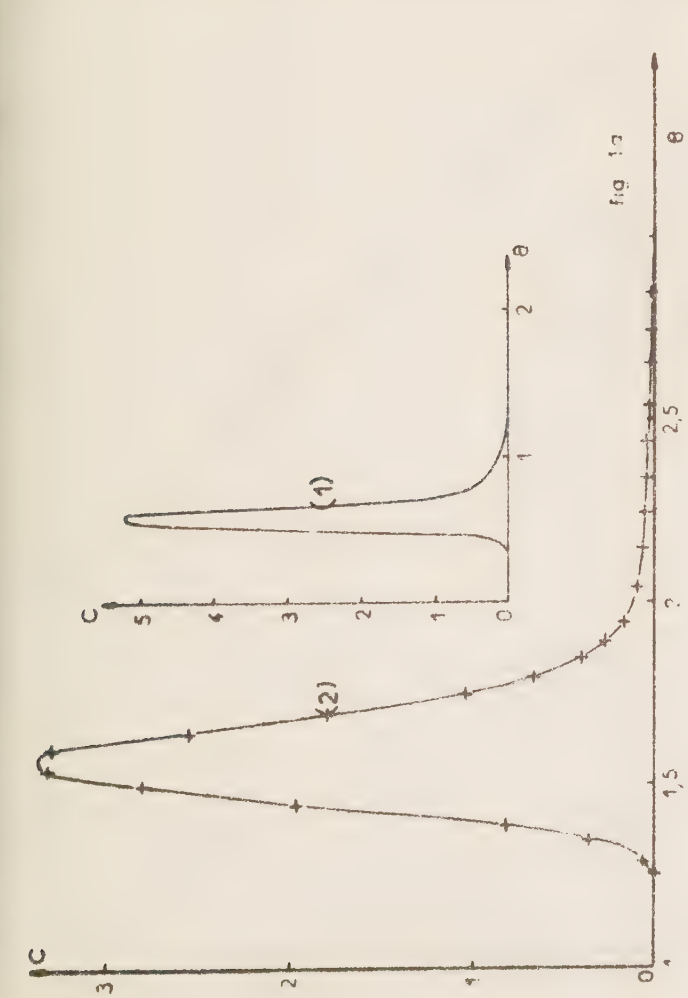
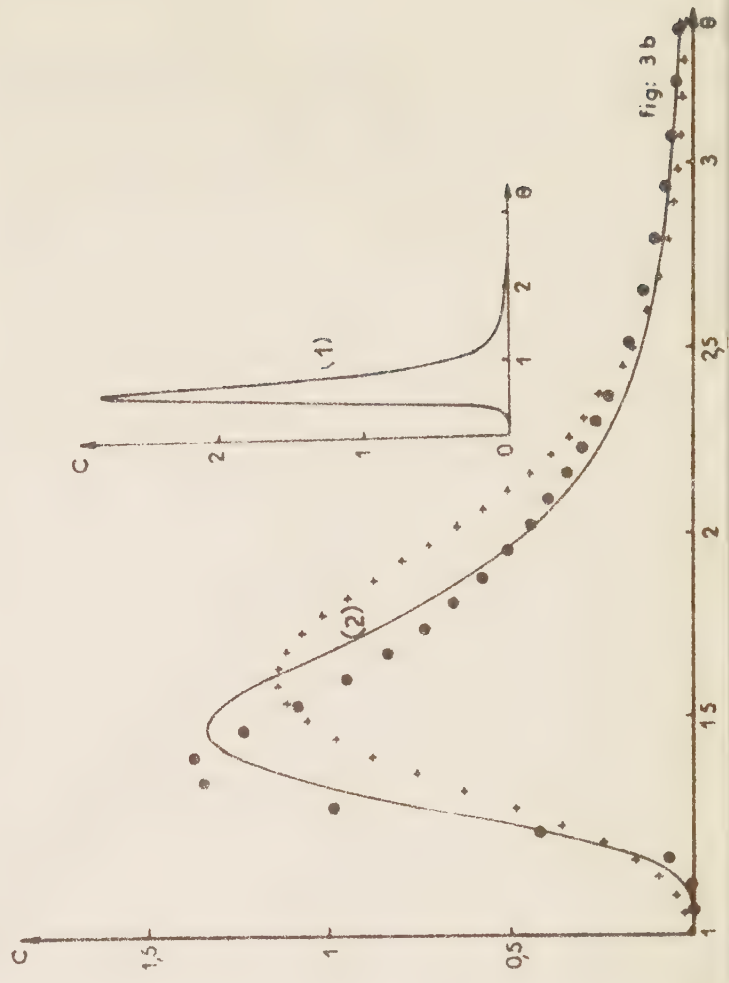
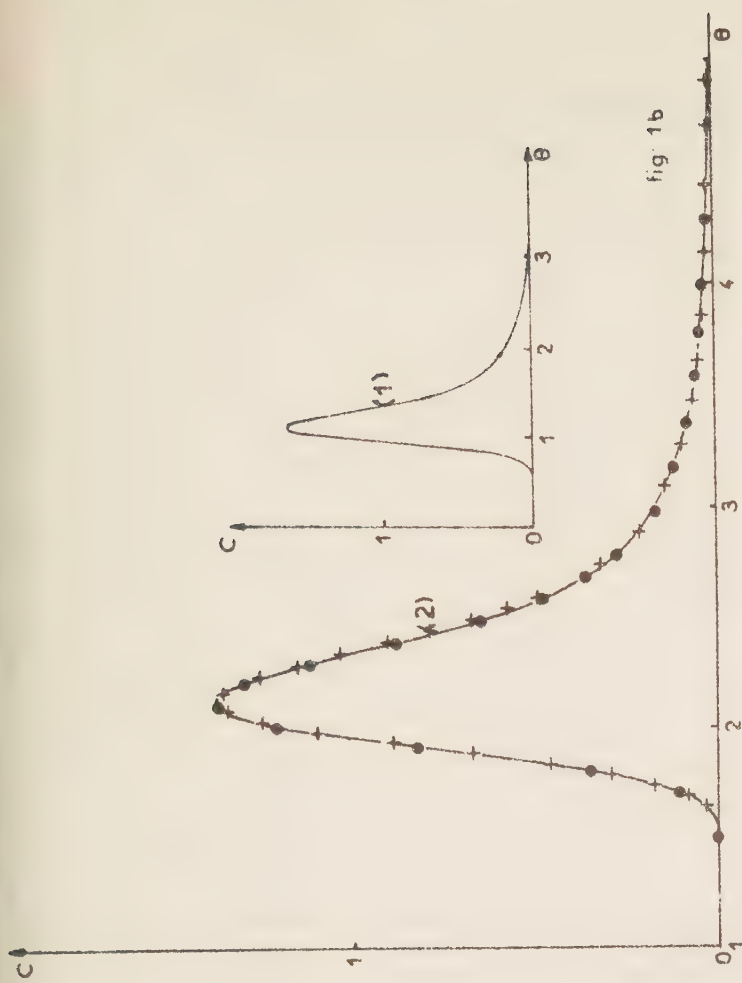
CONVOLUTIONS anneaux raschig 10,3

(1) 1^{er} courbe
modèle PD
expérimentale

(2) 2^{ème} courbe
modèle PE

		Modèle		PD +		Modèle		PE	
		L	G	P	T	N	ψ		
		kg.m ⁻¹	kg.m ⁻¹						
Fig 1	a	0	0,043	345,0	1,000				
"	b	2,3	0,267	1400	0,9963	1,535	0,8711		
Fig 2	a	6,5	0,0494	99,54	0,9945	2,5083	0,9151		
"	b	6,5	0,552	76,77	0,9783	0,4618	0,8641		
"	c	6,5	0,588	48,71	0,9356	0,2698	0,8096		
Fig 3	a	10,5	0,069	52,06	0,9855	1,345	0,783		
"	b	14,0	0,083	26,03	0,9616	1,078	0,6975		

Fig. VII 1.2.3



OPTIMISATION DES PARAMETRES DU MODELE P.D.

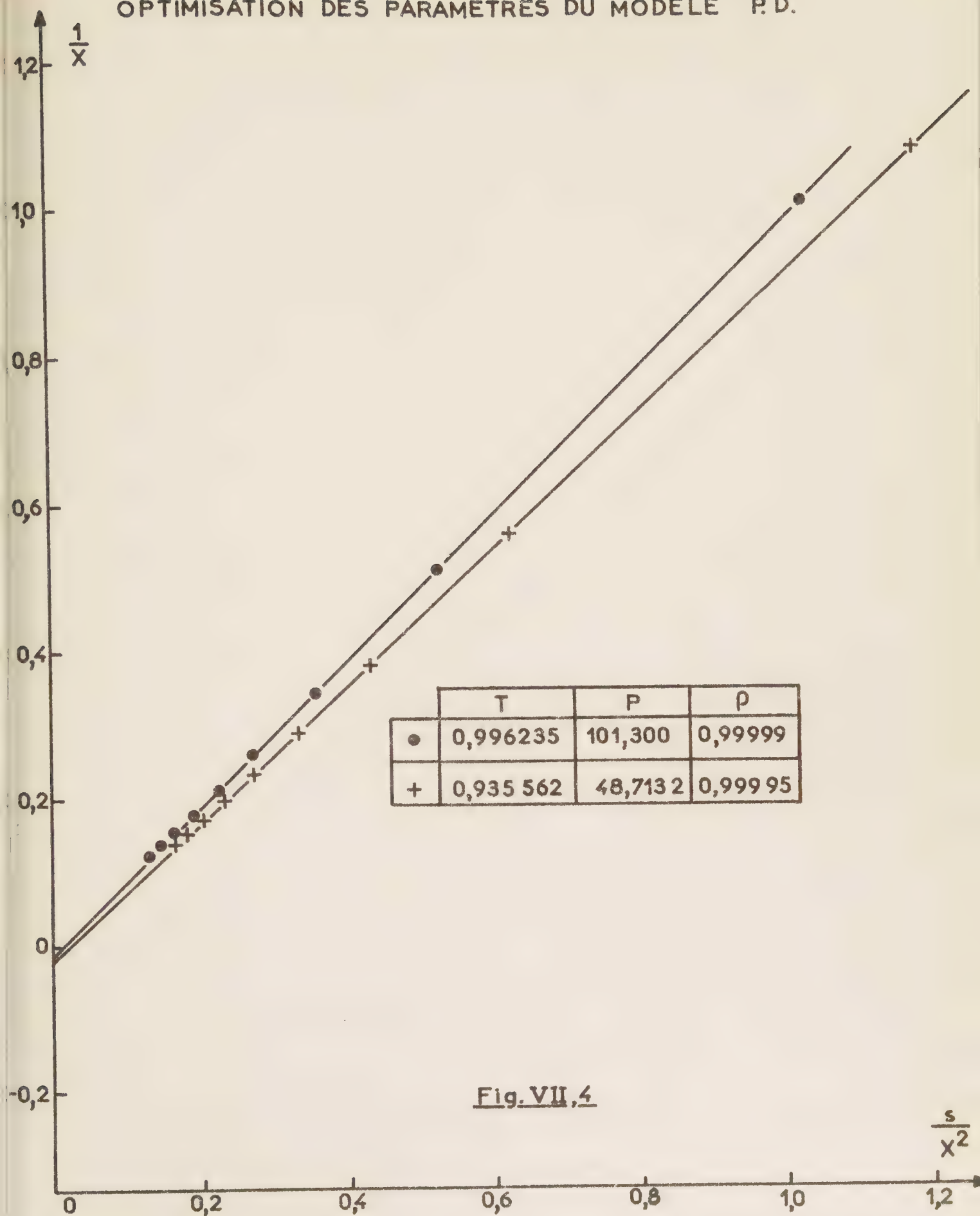


Fig. VII,4

$$\frac{1}{1-X/s}$$

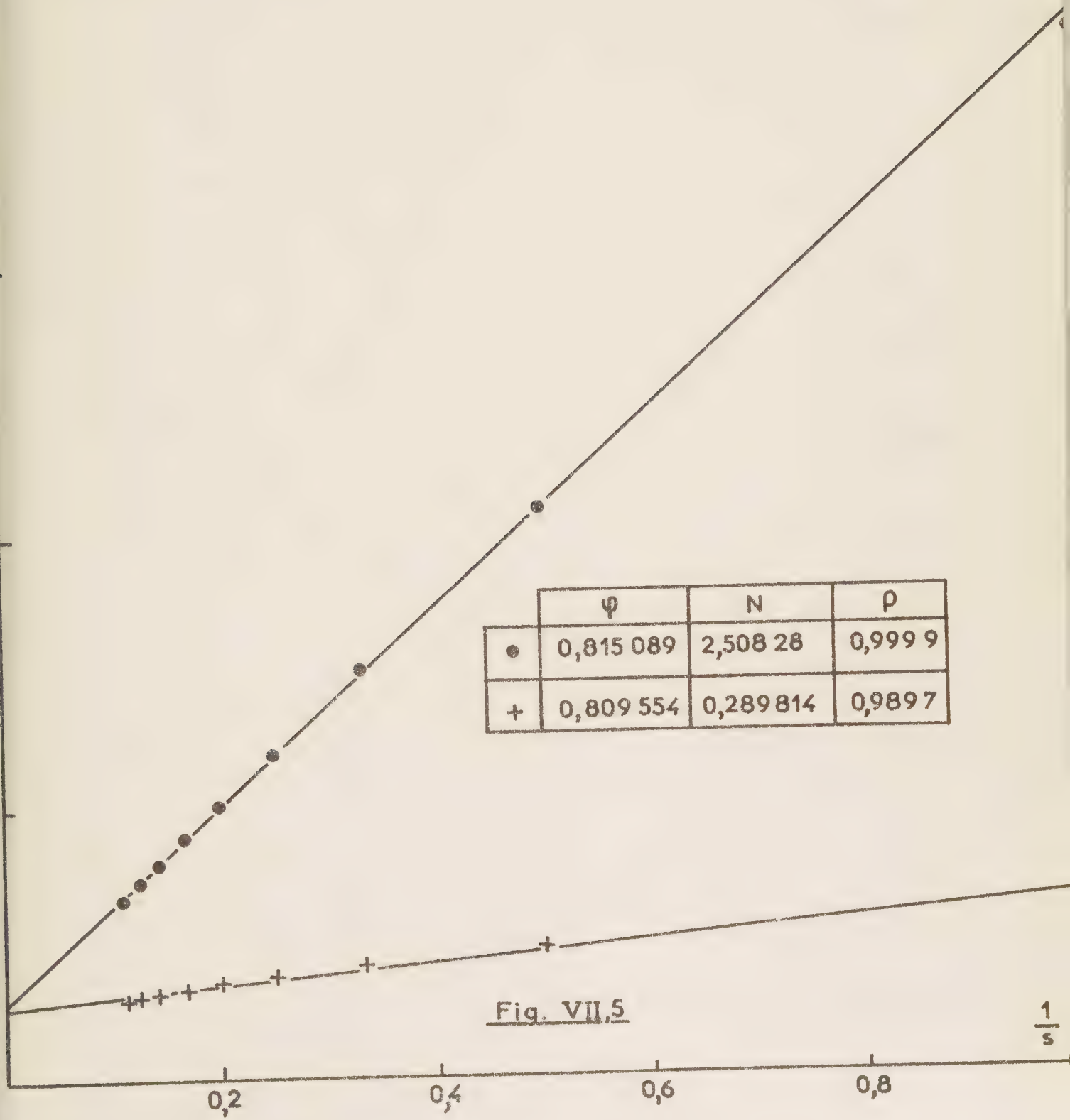


Fig. VII.5

$\frac{1}{s}$

OPTIMISATION DES PARAMETRES DU MODELE P.D.E.

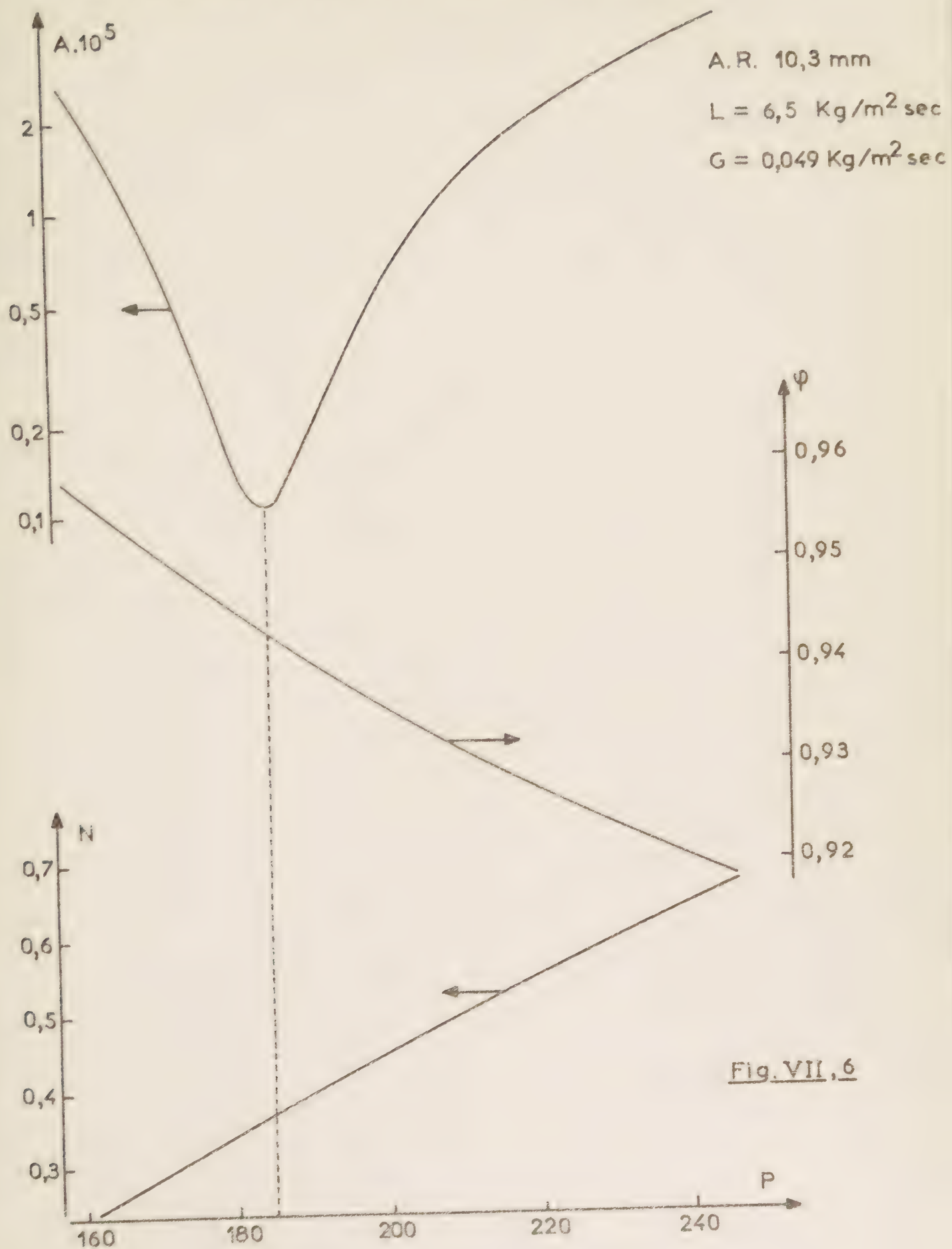


Fig. VII, 6

OPTIMISATION DES PARAMETRES DU MODELE R.D.E.

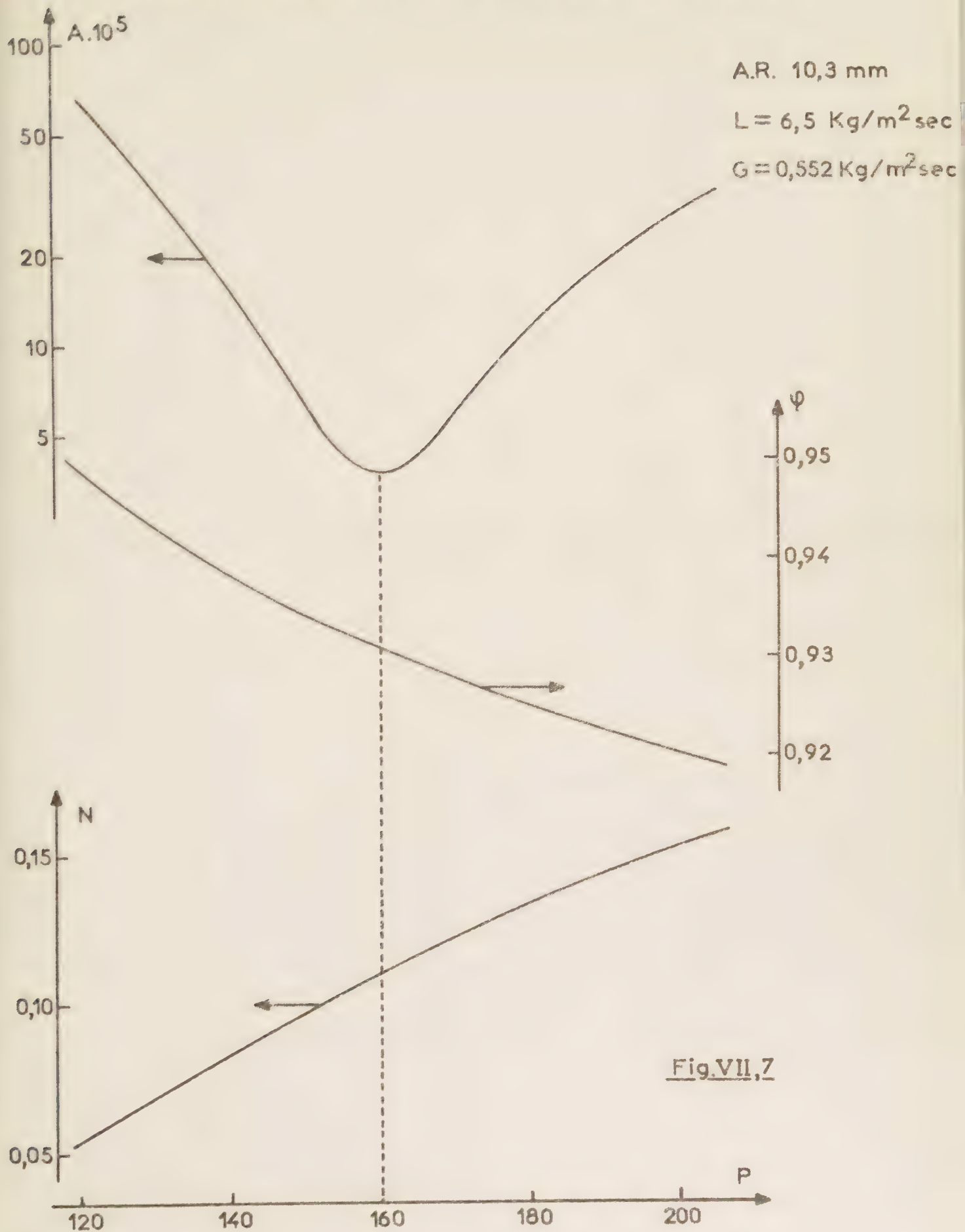
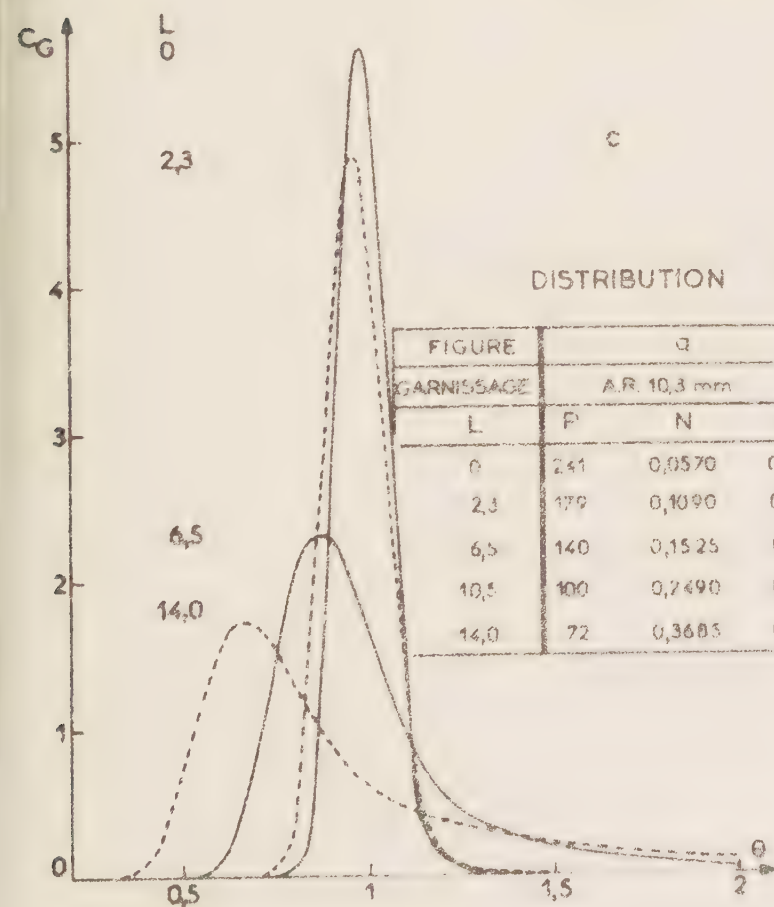
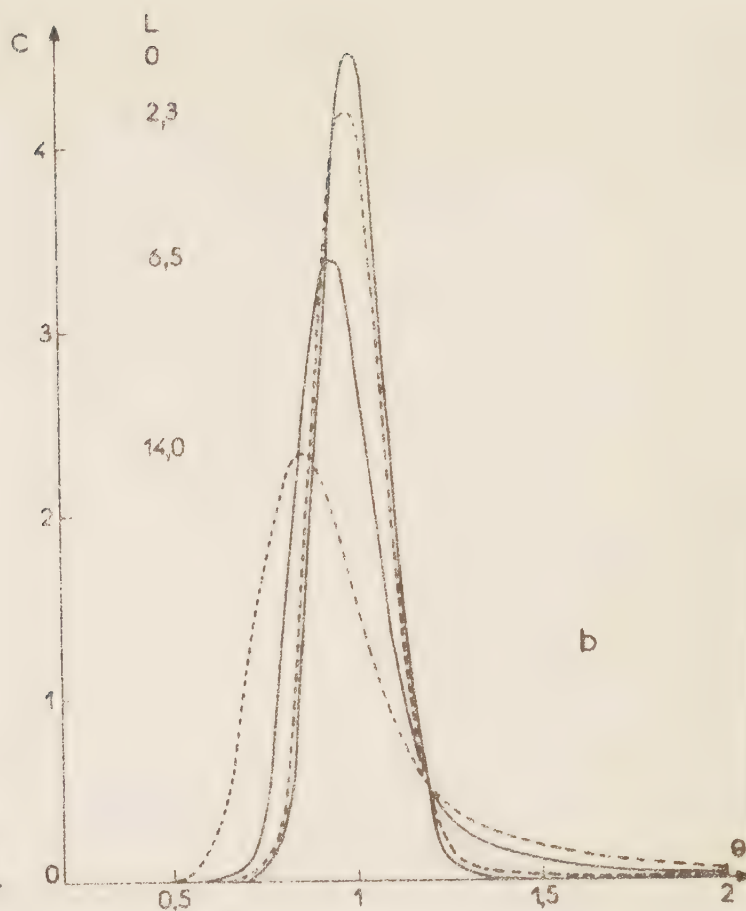
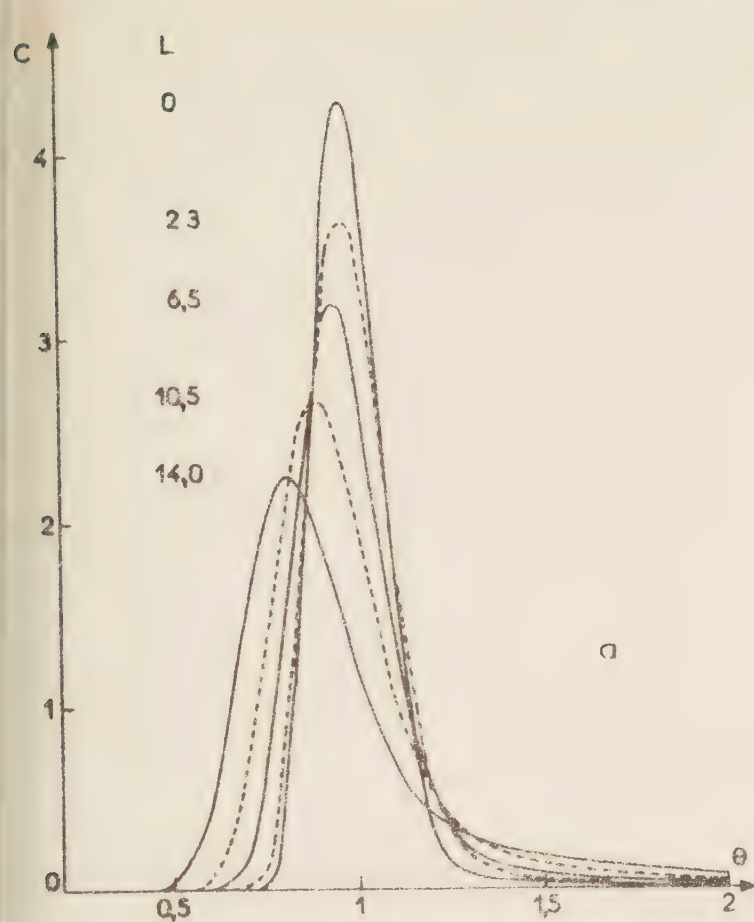


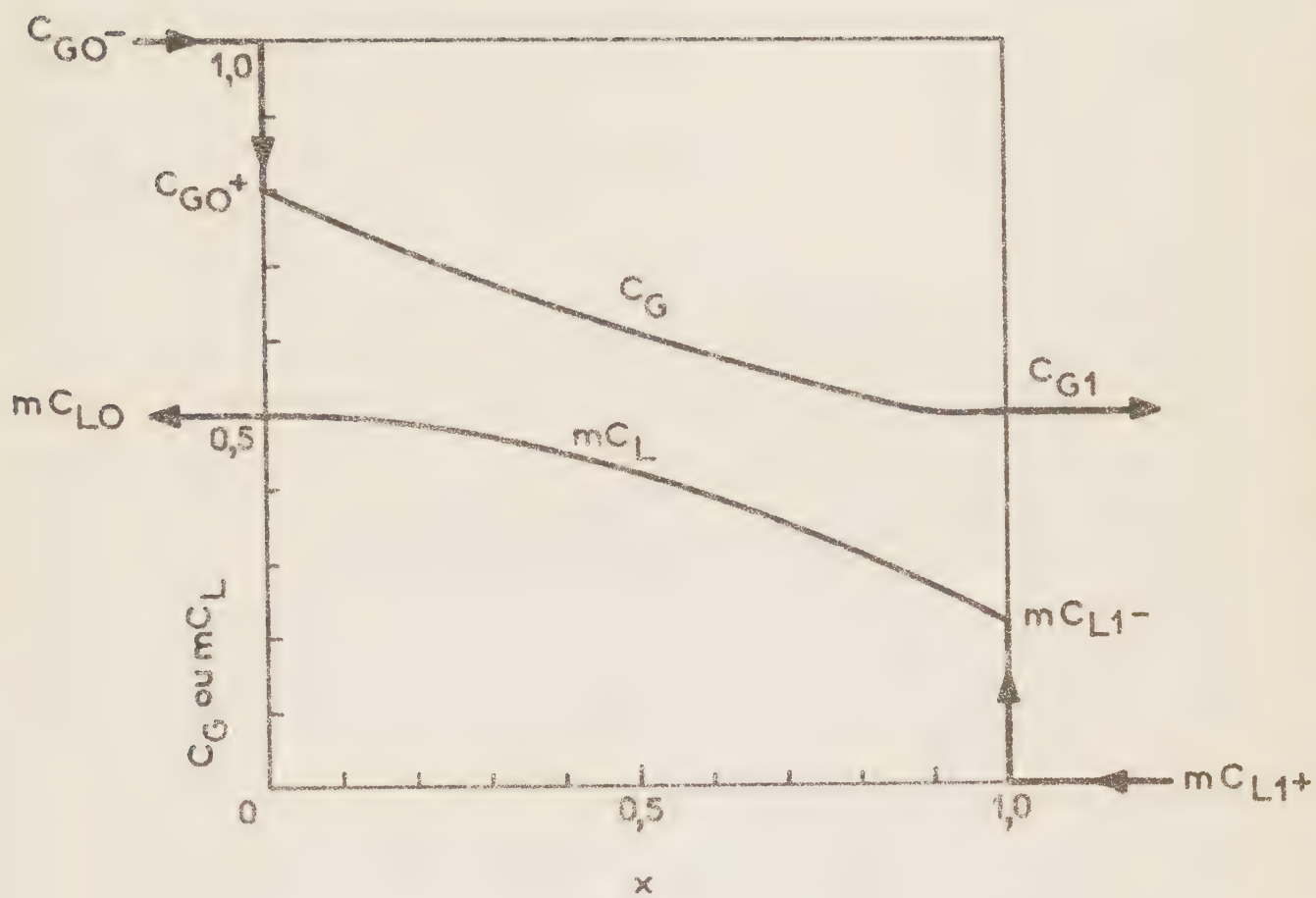
Fig.VII,7



DISTRIBUTION DES TEMPS DE SEJOUR

FIGURE	a			b			c		
GARNISSAGE	A.R. 10,3 mm			A.R. 64 mm			BILLES 10mm		
L	P	N	ψ	P	N	ψ	P	N	ψ
0	241	0,0570	0,9760	248	0,0001	0,9999	401	0,0180	0,9880
2,3	179	0,1090	0,9755	235	0,0455	0,9865	286	0,0210	0,9665
6,5	140	0,1525	0,9495	172	0,2340	0,9440	88	0,4000	0,8820
10,5	100	0,2490	0,9090	84	0,4010	0,8695	44	0,6600	0,6940
14,0	72	0,3685	0,8365						

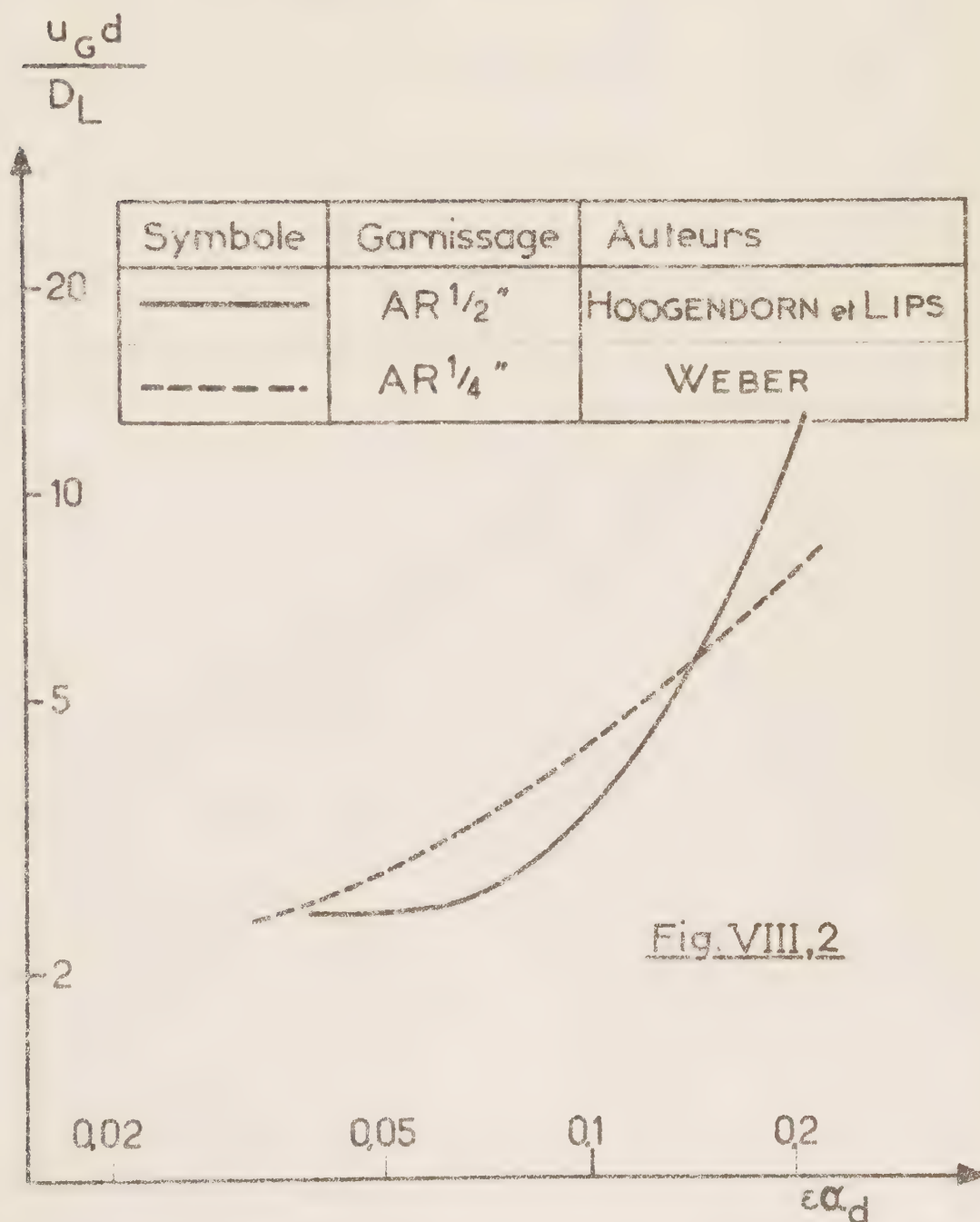
Fig. VII.2



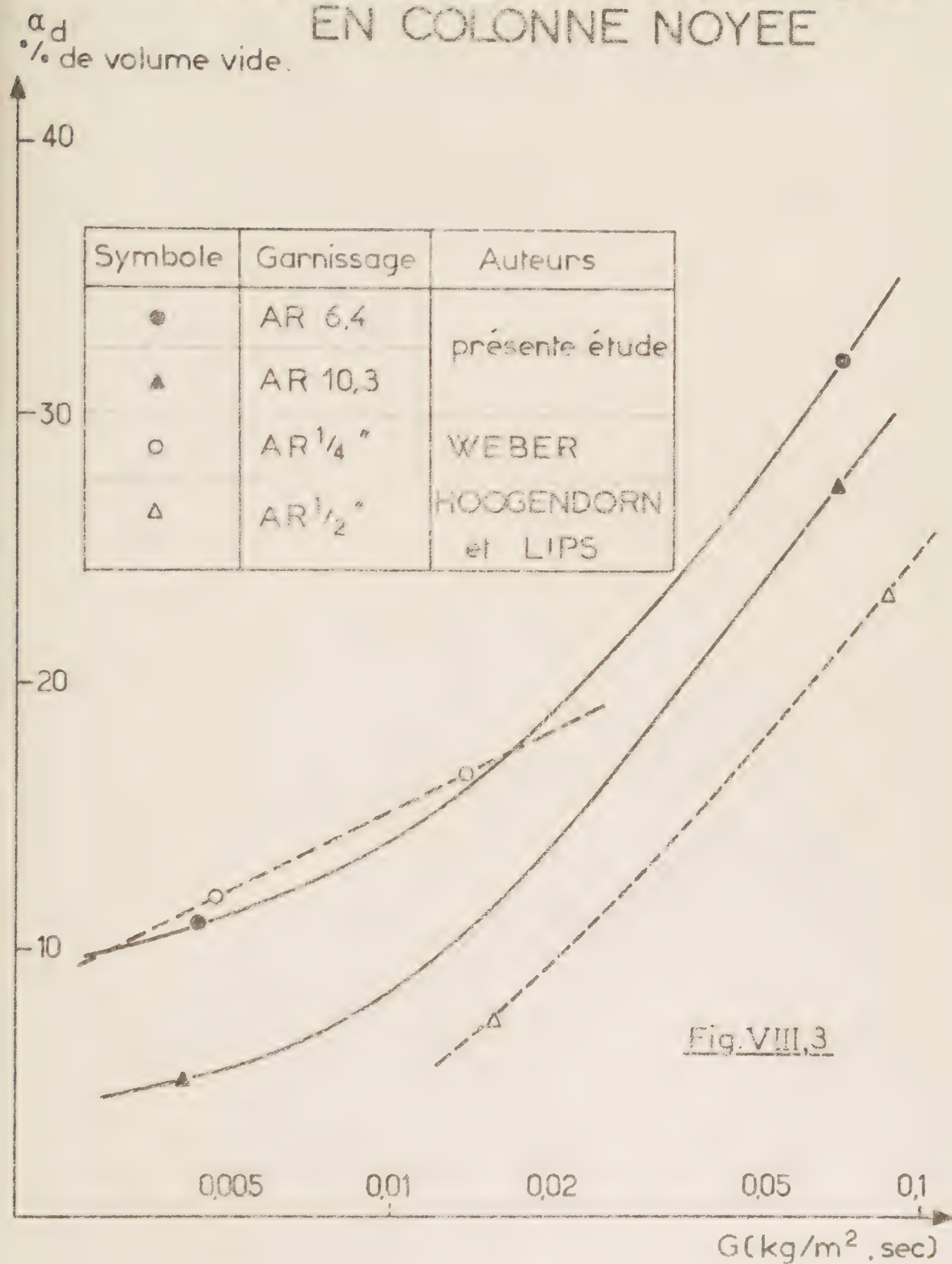
PROFILS DE CONCENTRATION

Fig. VIII.1

COEFFICIENT DE DISPERSION AXIALE DU LIQUIDE EN COLONNE NOYEE



TAUX DE RETENTION DU GAZ EN COLONNE NOYEE



CRITERE DE BODENSTEIN DE LA PHASE GAZEUSE EN COLONNE NOYEE

Symbole	L(kg/m ² sec)	Garnissage	Auteurs
▲	0	AR 6,4mm	Présente étude.
●	6,5		
▼	14,0		
△	0	AR 10,3mm	
○	6,5		
▽	14,0		
---		AR 6mm	CARLETON et COLL
---		AR 10mm	

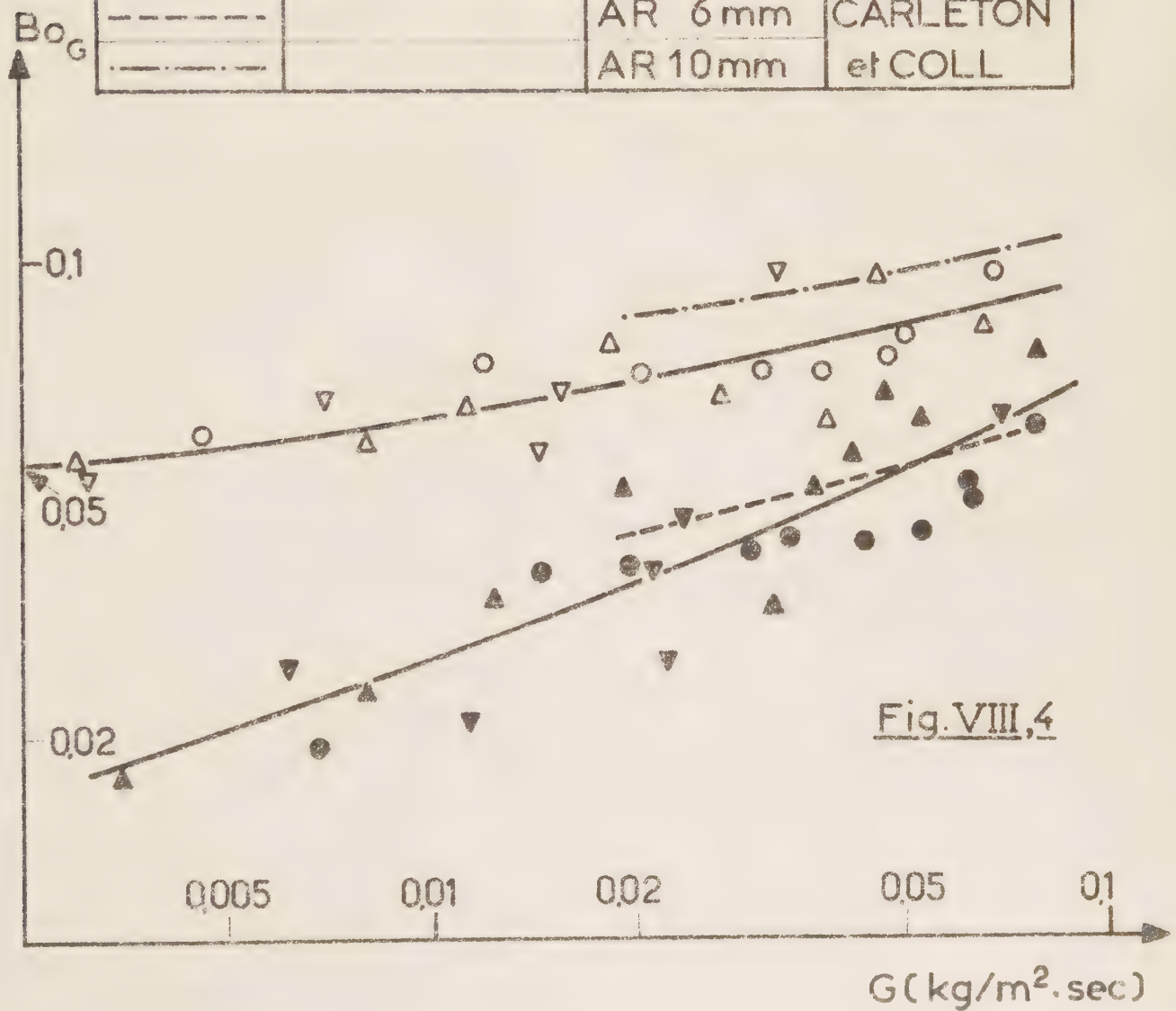
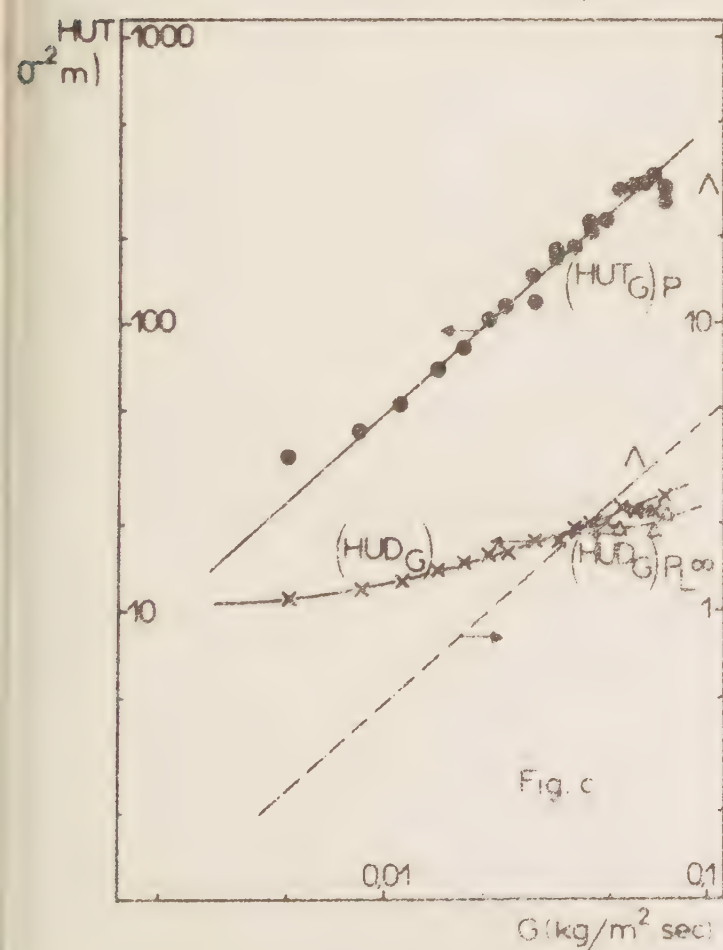
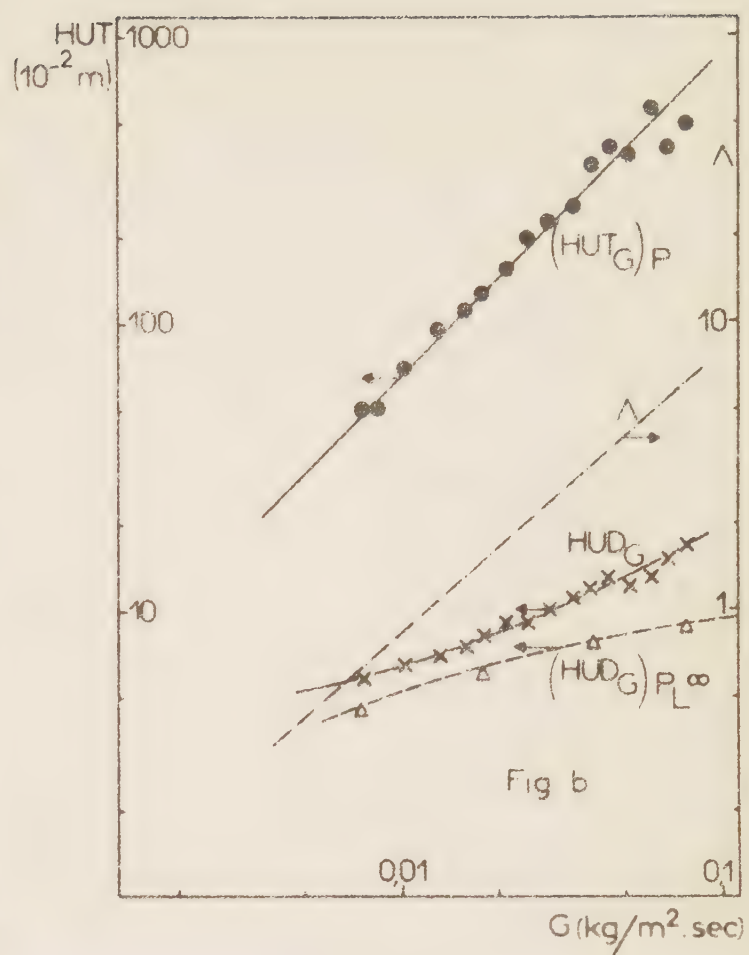
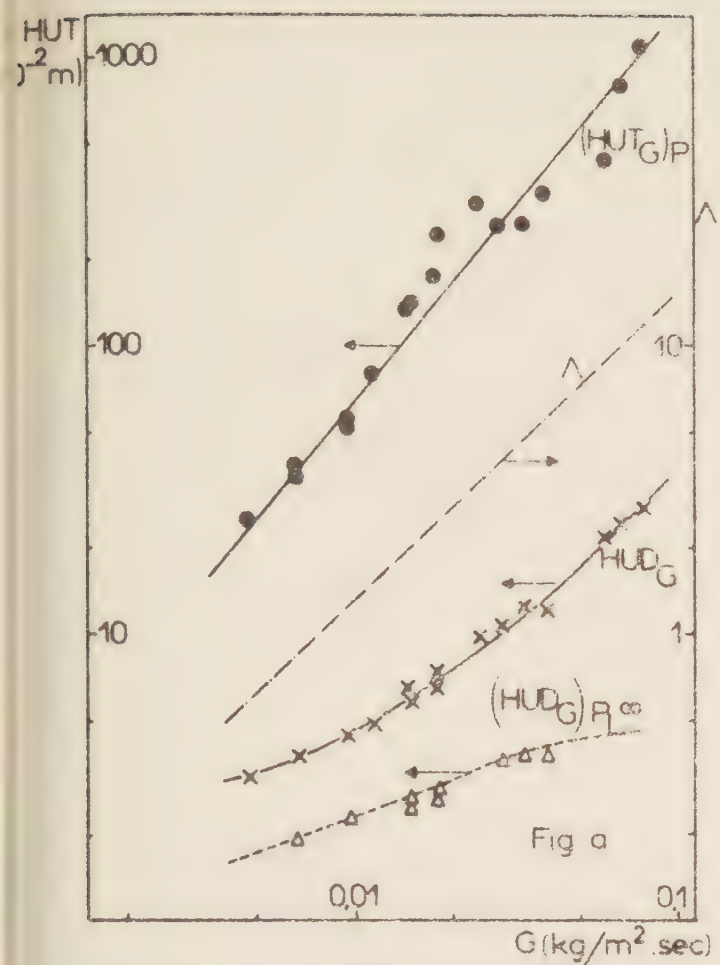


Fig.VIII,4

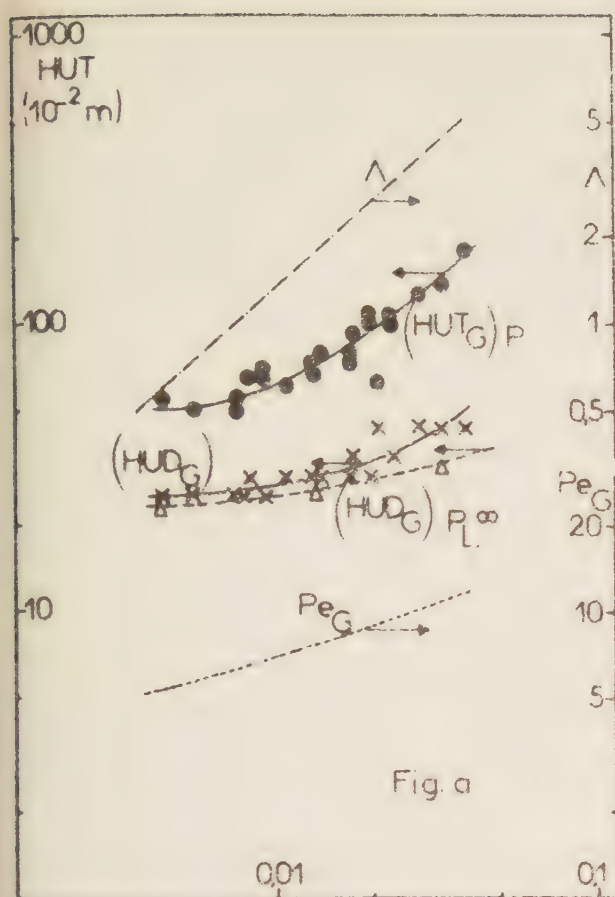


VARIATIONS DE $(HUT_G)_P$ ET HUD_G
EN FONCTION DE G
COLONNE ARROSEE

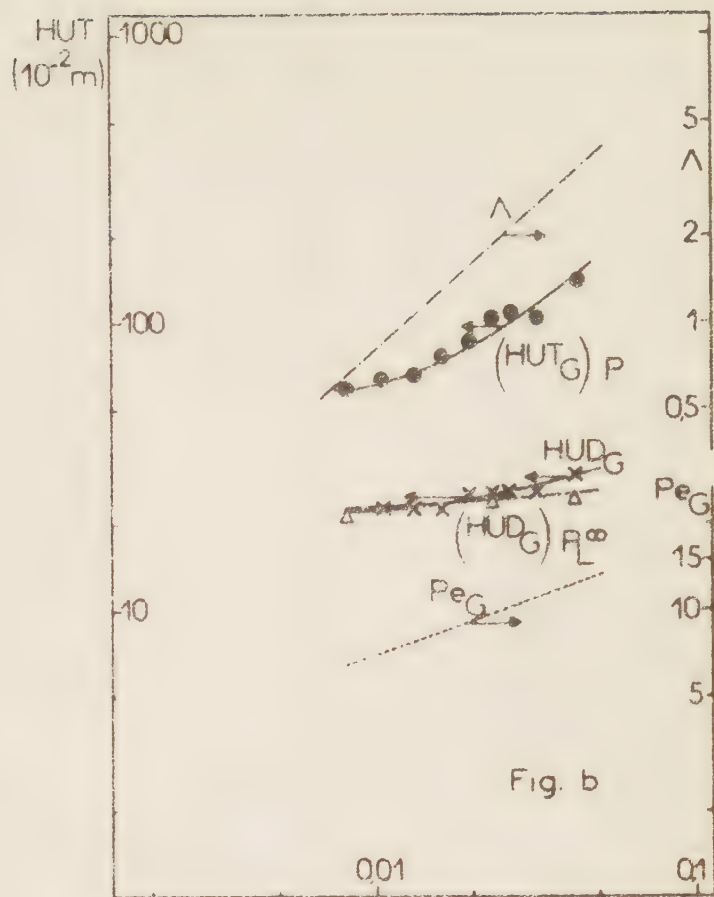
A.R. 6,4 mm

Fig	L kg/m ² .sec	Pe_G	Pe_L
a	6,5	88,5	83
b	11,2	32	119
c	16	11,5	155

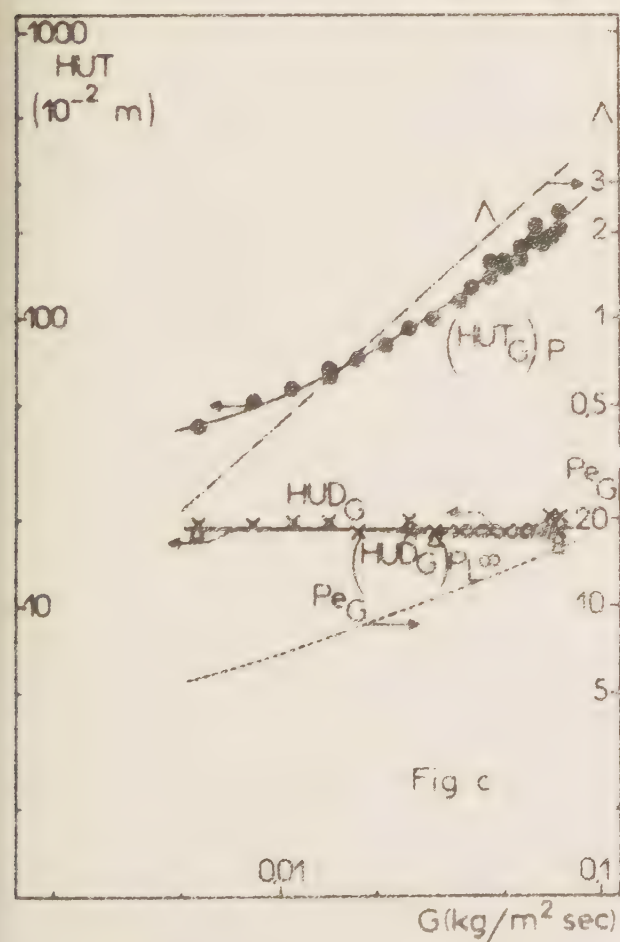
Fig VIII.5



$G(\text{kg}/\text{m}^2 \text{ sec})$



$G(\text{kg}/\text{m}^2 \text{ sec})$

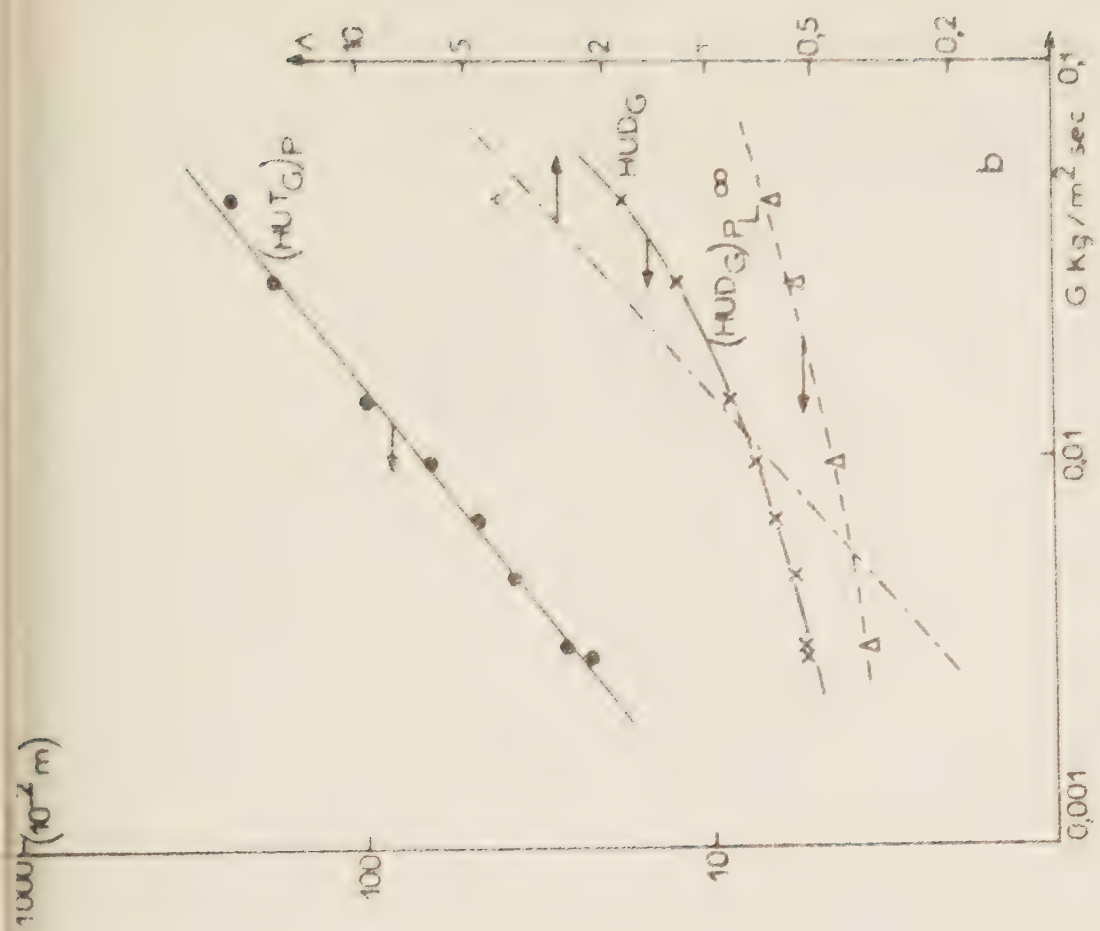
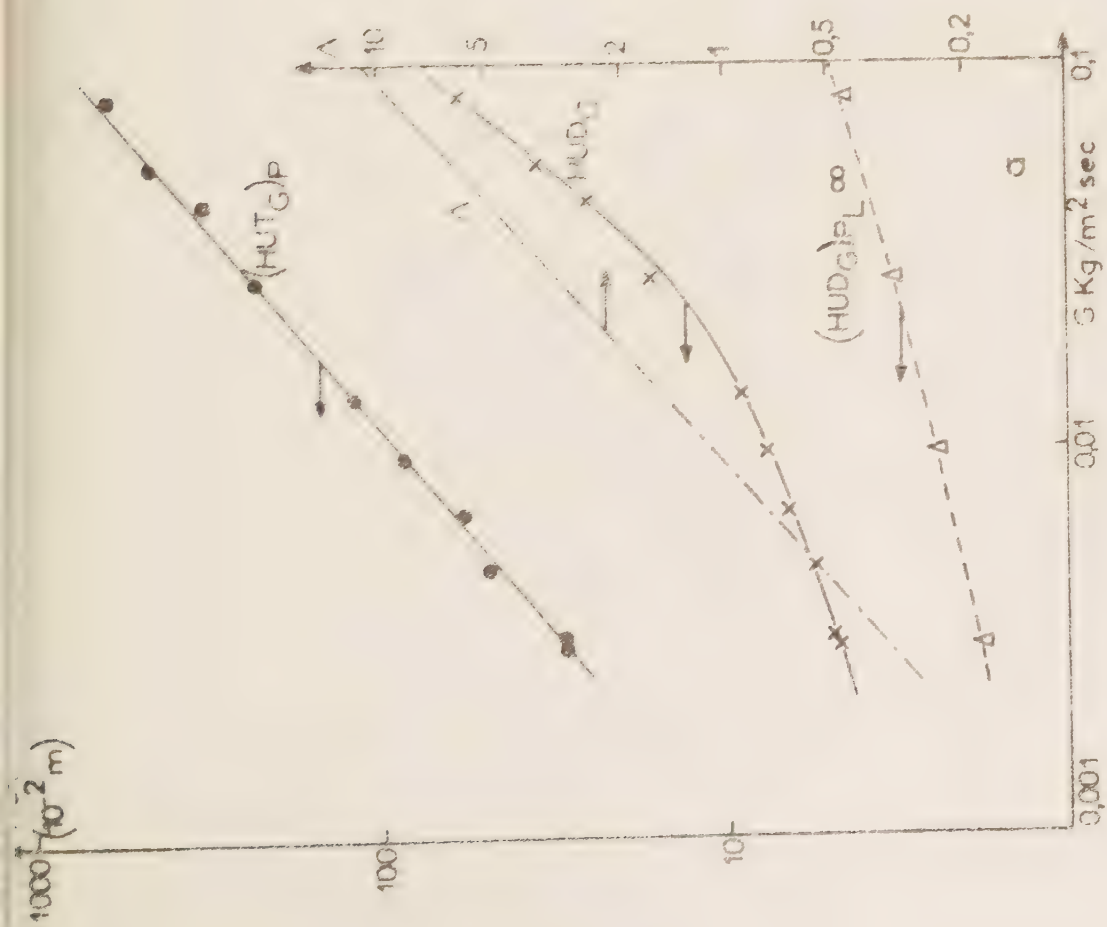


$G(\text{kg}/\text{m}^2 \text{ sec})$

VARIATIONS DE $(HUT_G)_P$ ET HUD_G
EN FONCTION DE G
COLONNE NOYEE
AR 6,4 mm

Fig.	G $\text{kg}/\text{m}^2 \text{ sec}$	Pe_L
a	6,5	93
b	11,2	160
c	16	229

Fig. VIII.6



VARIATIONS DE $(HUT_G)_P$ ET HUD_G EN

FONCTION DE G
COLONNE ARROSEE

A.R. 10,3 mm

Fig. VIII.7

Fig.	L $Kg/m^2 \text{ sec}$	P_G	P_L
a	6,95	72,6	33,8
b	11,11	35,0	44,6

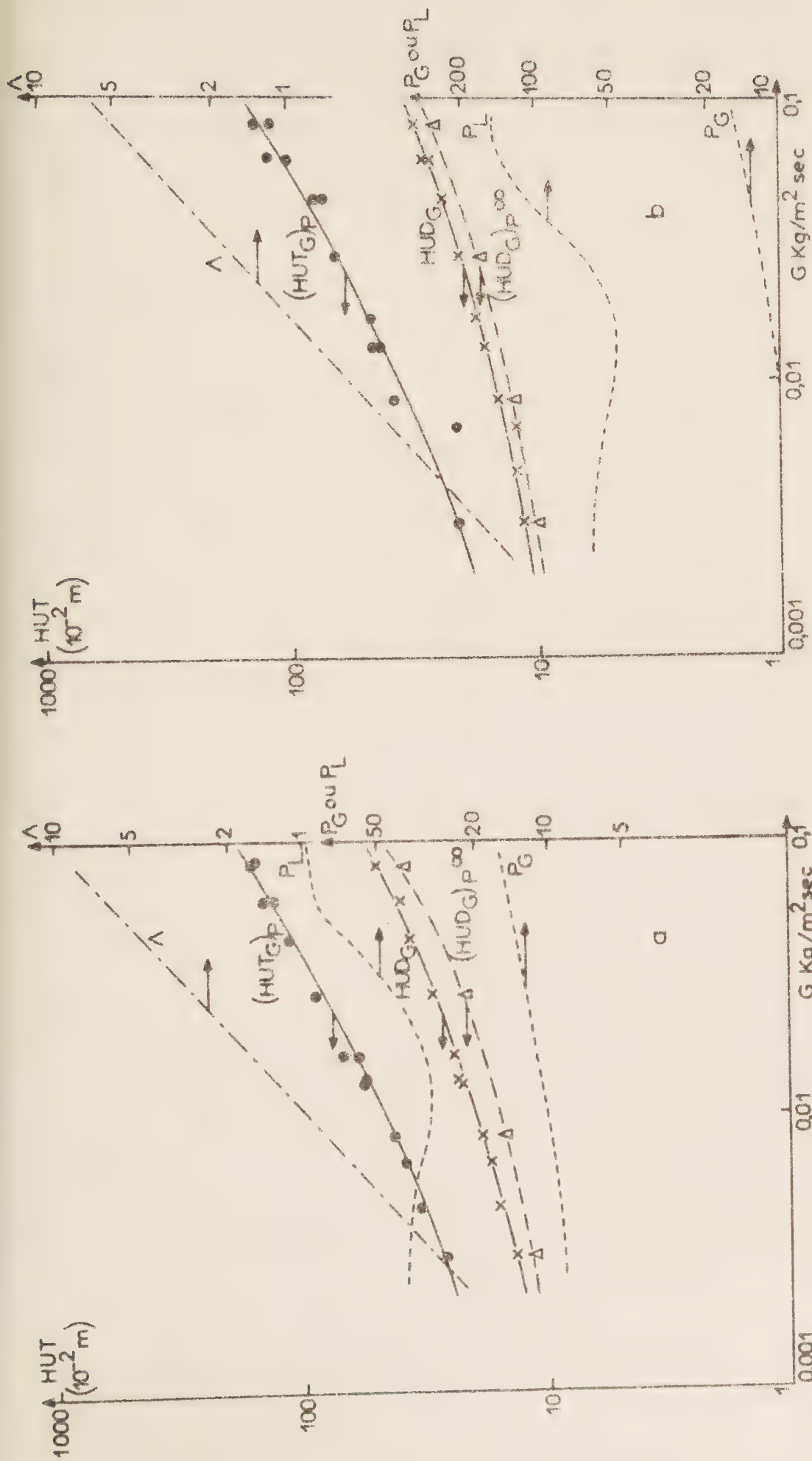


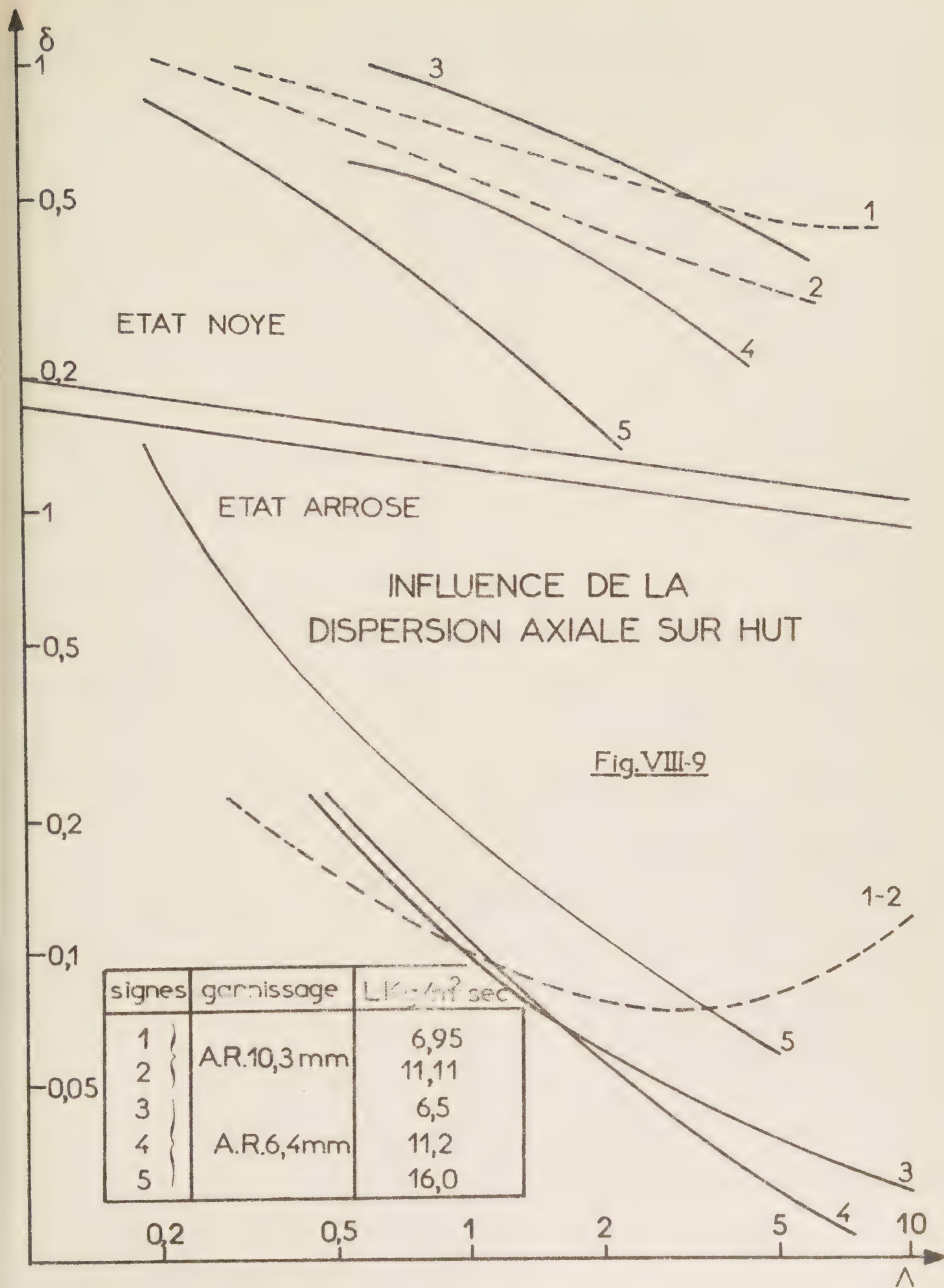
Fig.	L $\text{Kg/m}^2 \text{sec}$
a	6,95
b	11,11

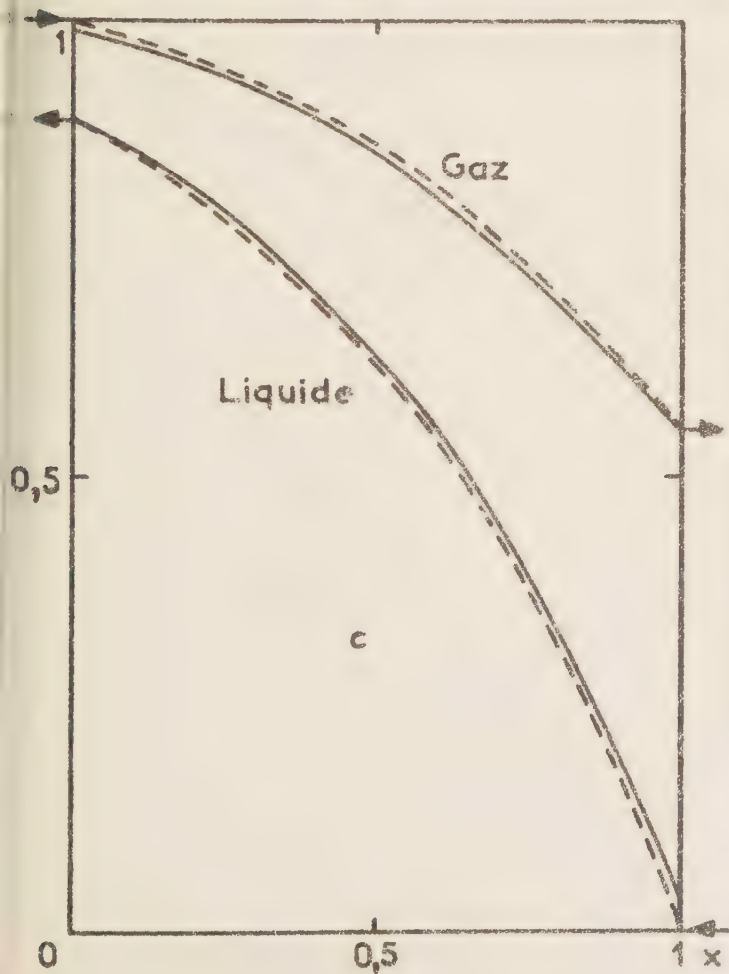
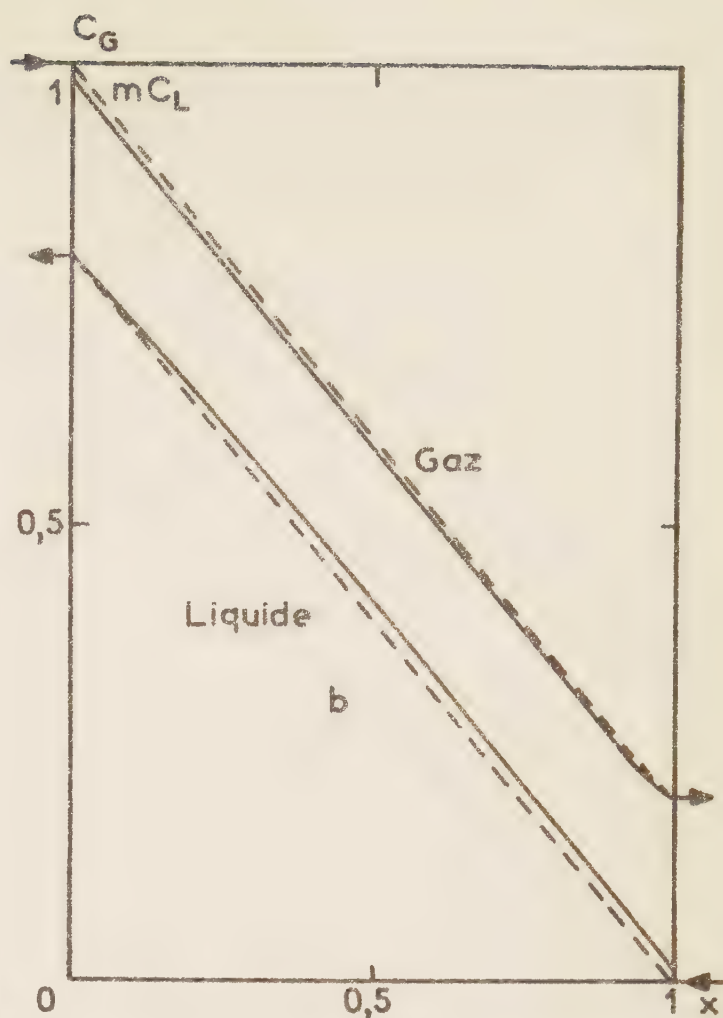
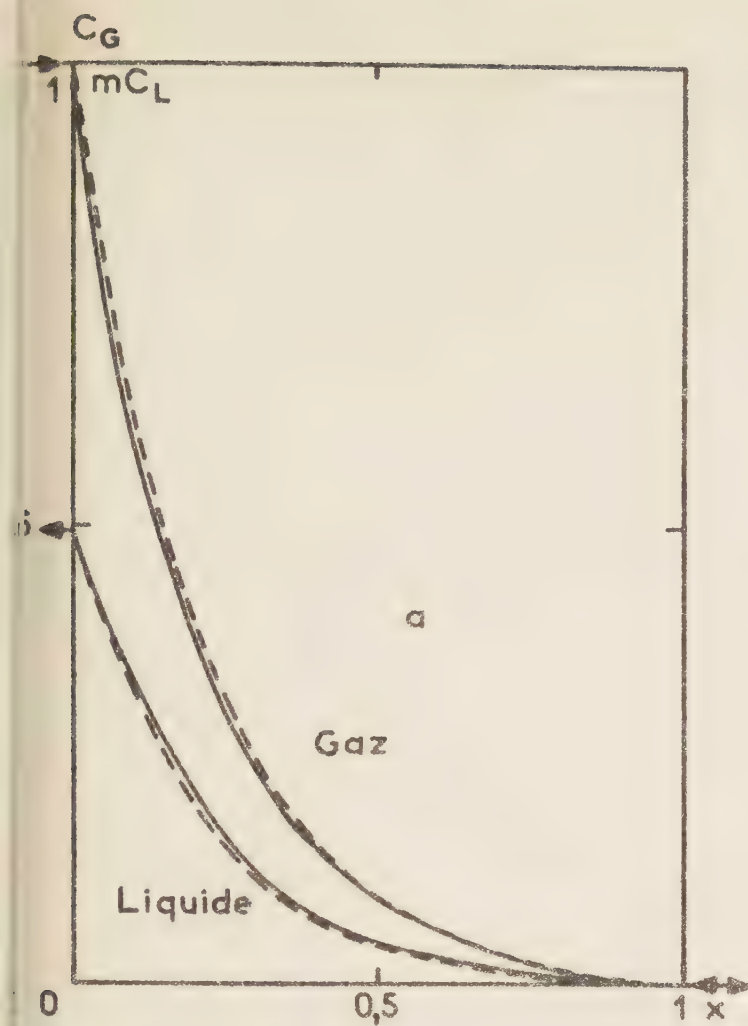
VARIATIONS DE $(HUT_G)/P$ EN FONCTION DE G

COLONNE NOYEE

AR. 10,3 mm

Fig. VIII, 8





PROFILS DE CONCENTRATIONS

A.R. 6,4 mm

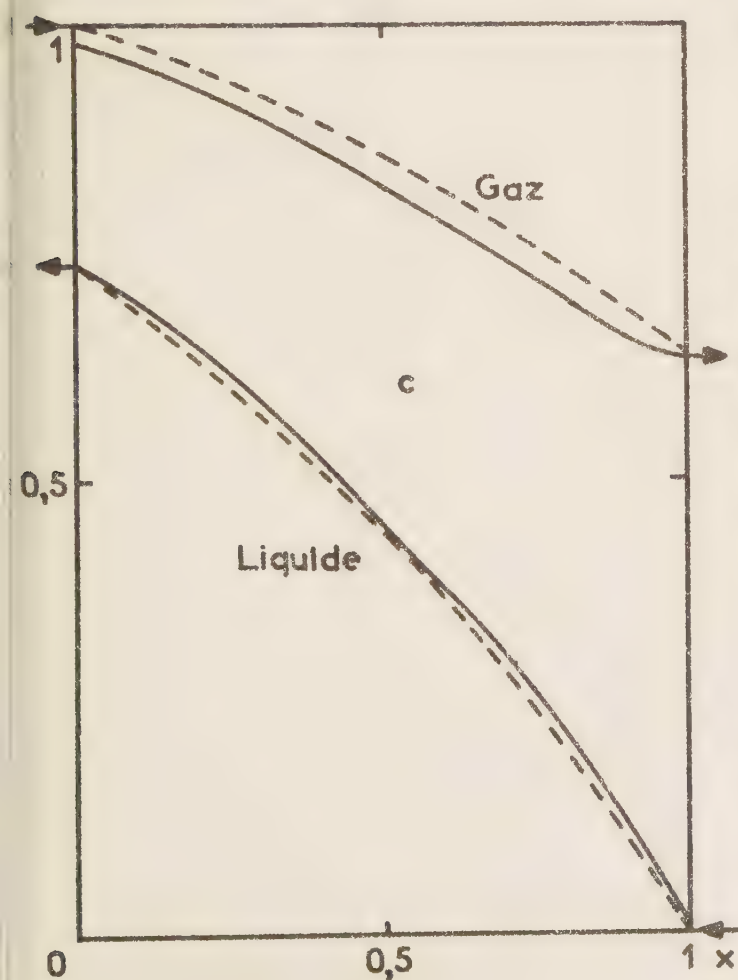
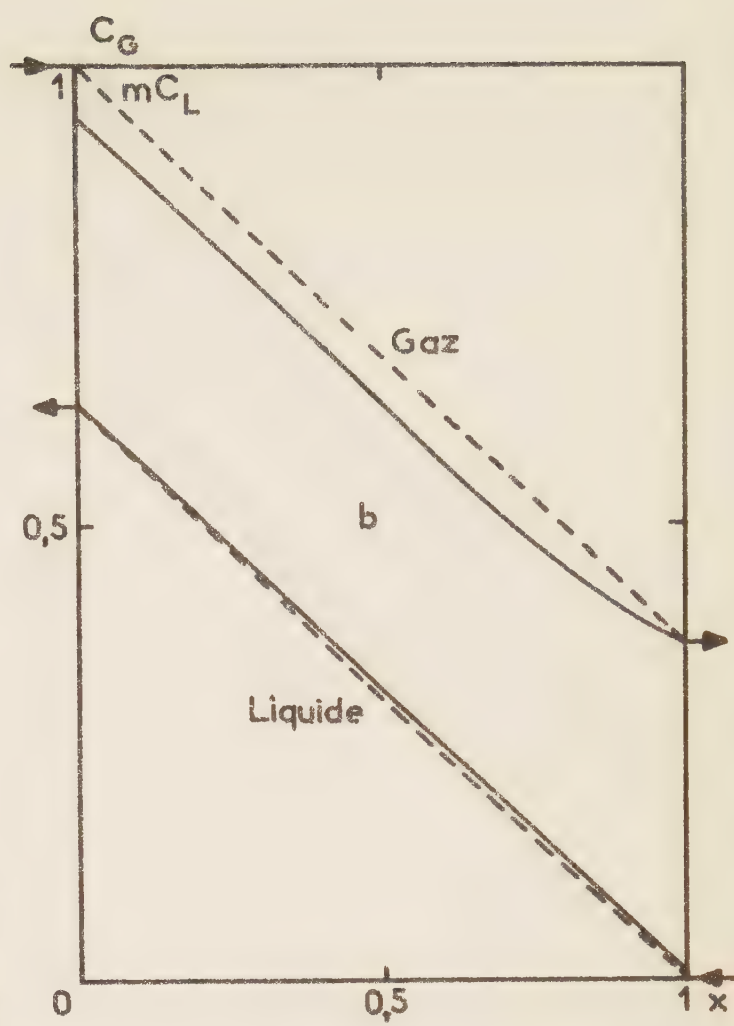
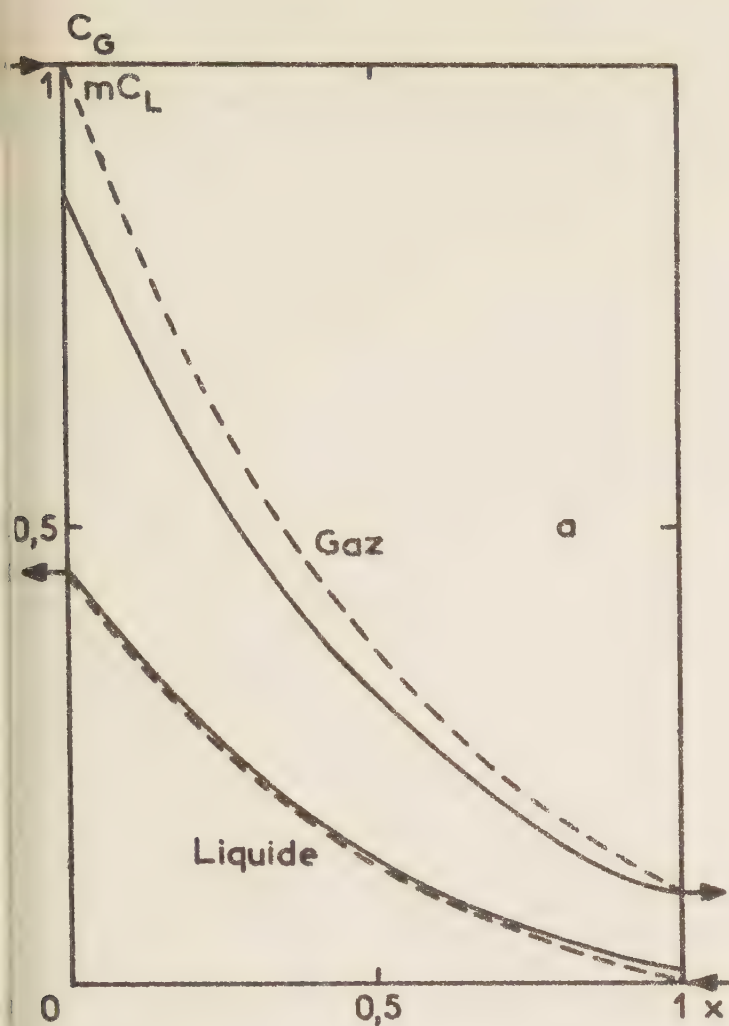
$L=6,5 \text{ Kg/m}^2 \text{ sec}$

ARROSE

Fig.	a	b	c
$(NUT_G)_P$	9,25	3,87	1,638
$(NUT_G)_V$	11,1	4,25	1,733
P_G	88,5	88,5	88,5
P_L	83,0	83,0	83,0
Λ	0,5	1,0	2,0

--- Ecoulement Piston
 — Ecoulement Piston Diffusionnel

Fig. VIII.10



PROFILS DE CONCENTRATIONS

A.R. 6,4 mm

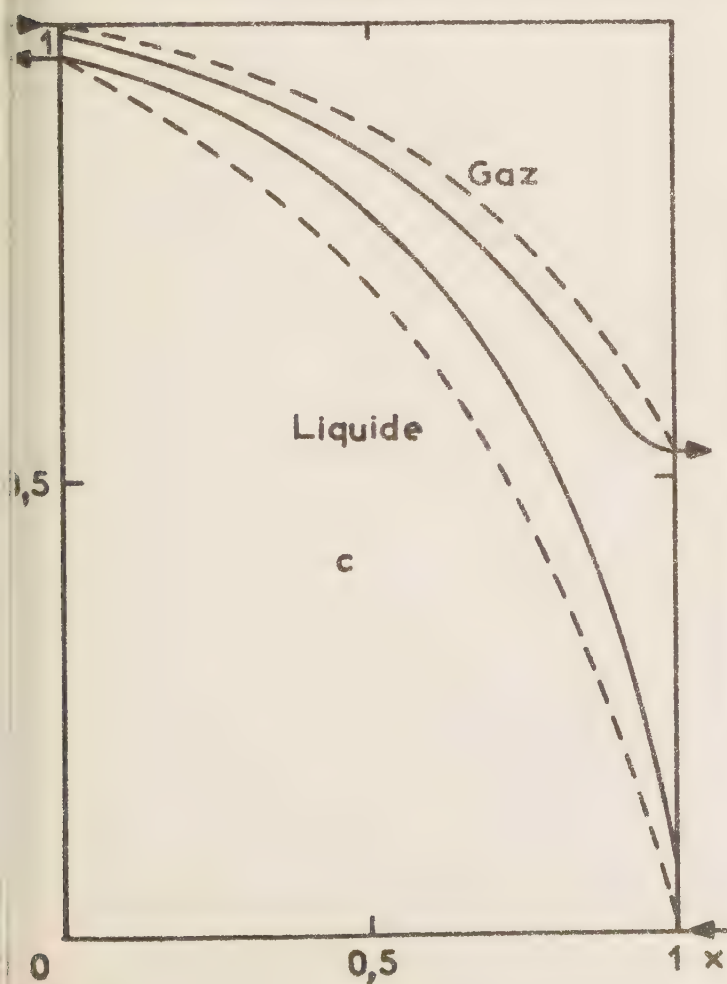
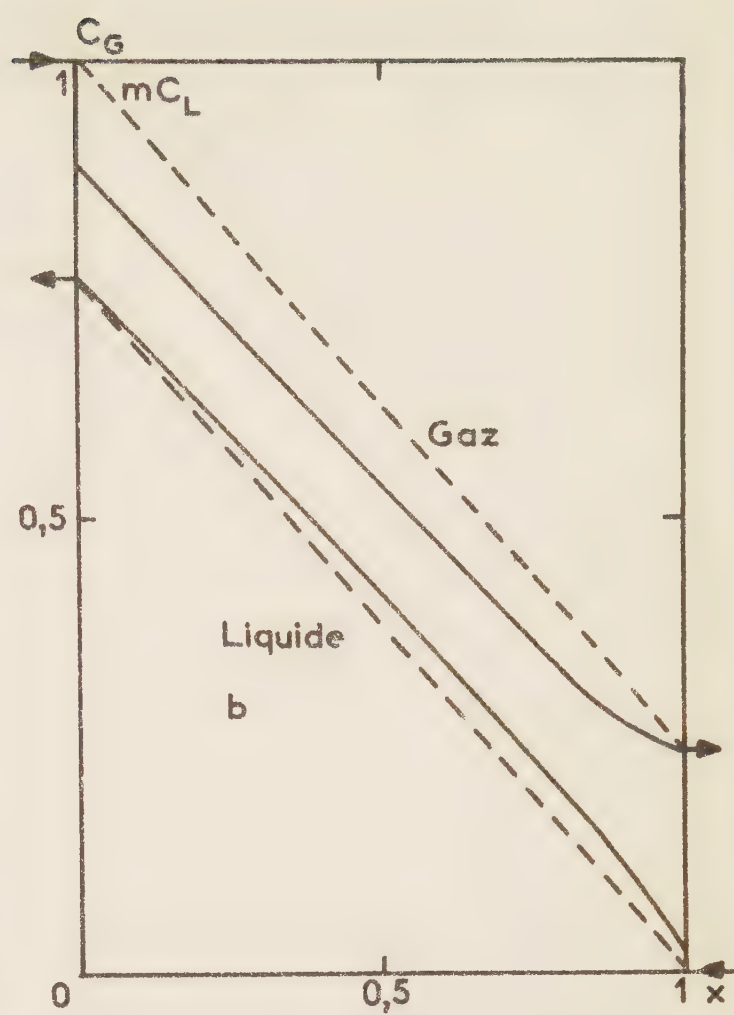
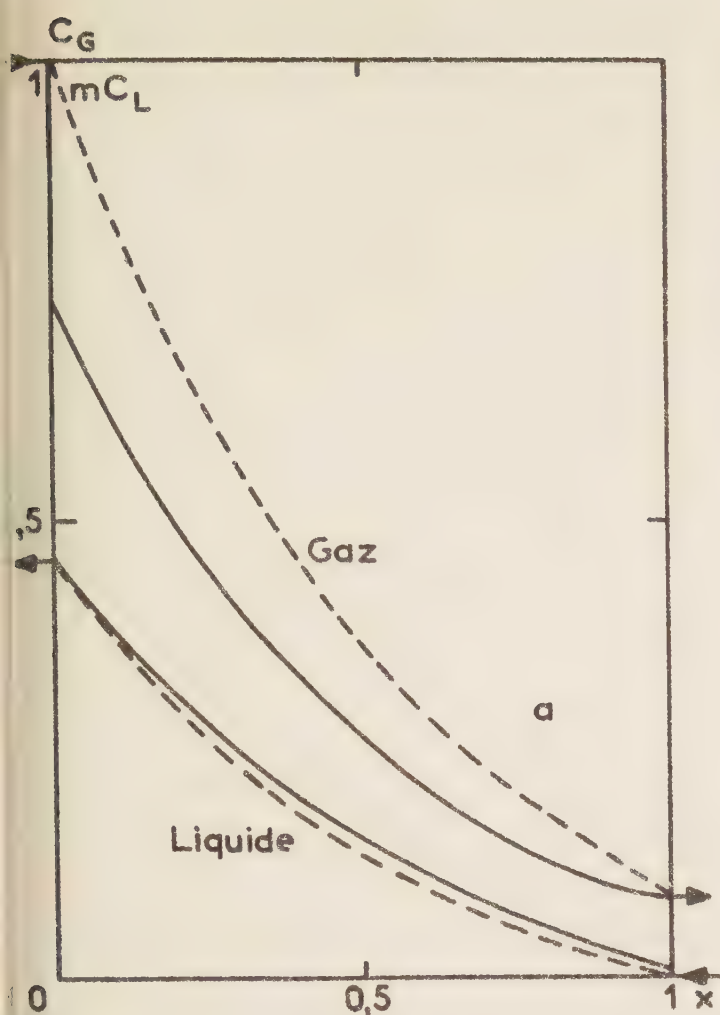
$L=16 \text{ Kg/m}^2.\text{sec}$

ARROSE

Fig.	a	b	c
$(NUT_G)P$	3,45	1,69	0,425
$(NUT_G)V$	4,58	1,99	0,453
P_G	11,5	11,5	11,5
P_L	155	155	155
Λ	0,5	1,0	2,0

--- Ecoulement Piston
 — Ecoulement Piston Diffusionnel

Fig. VIII.11



PROFILS DE CONCENTRATIONS

A. R. 6,4 mm

$L = 6,5 \text{ Kg/m}^2\text{sec}$

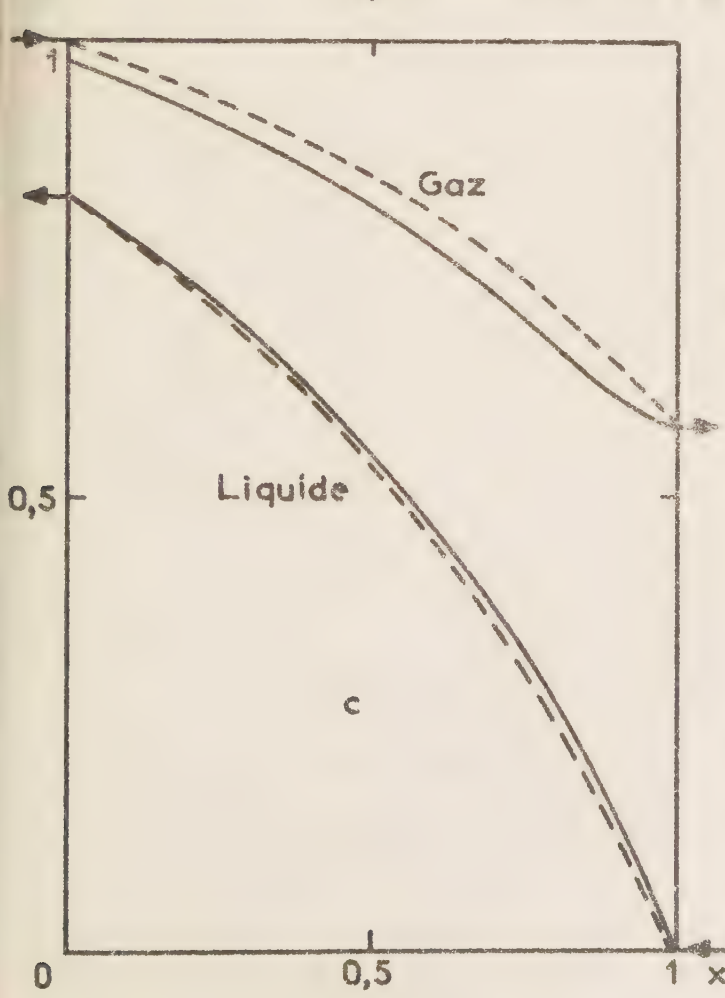
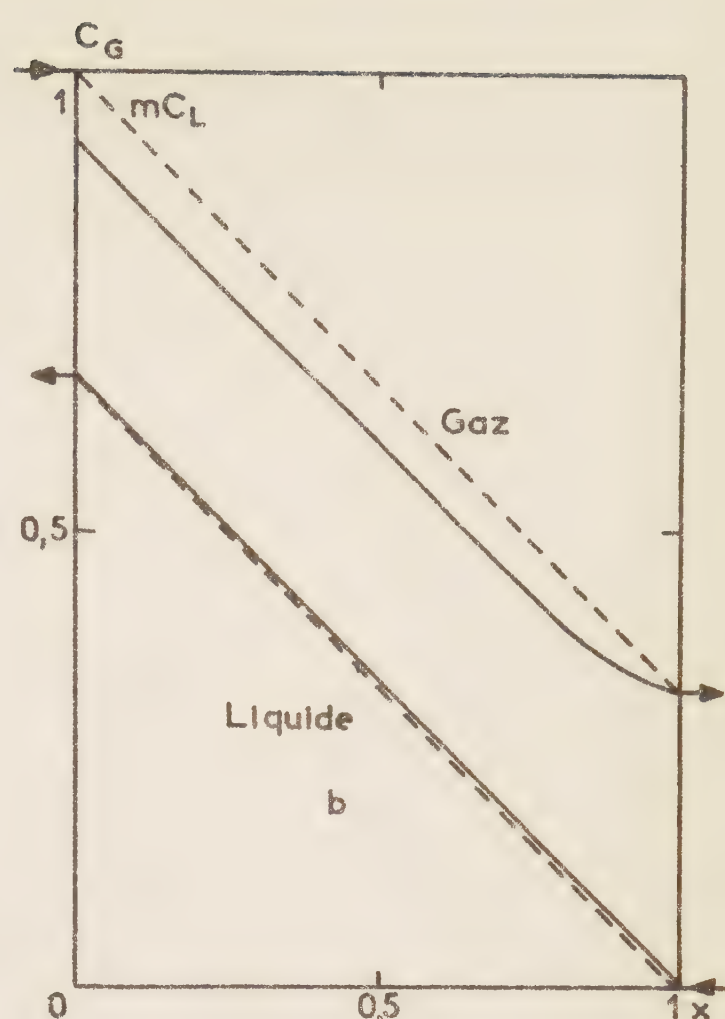
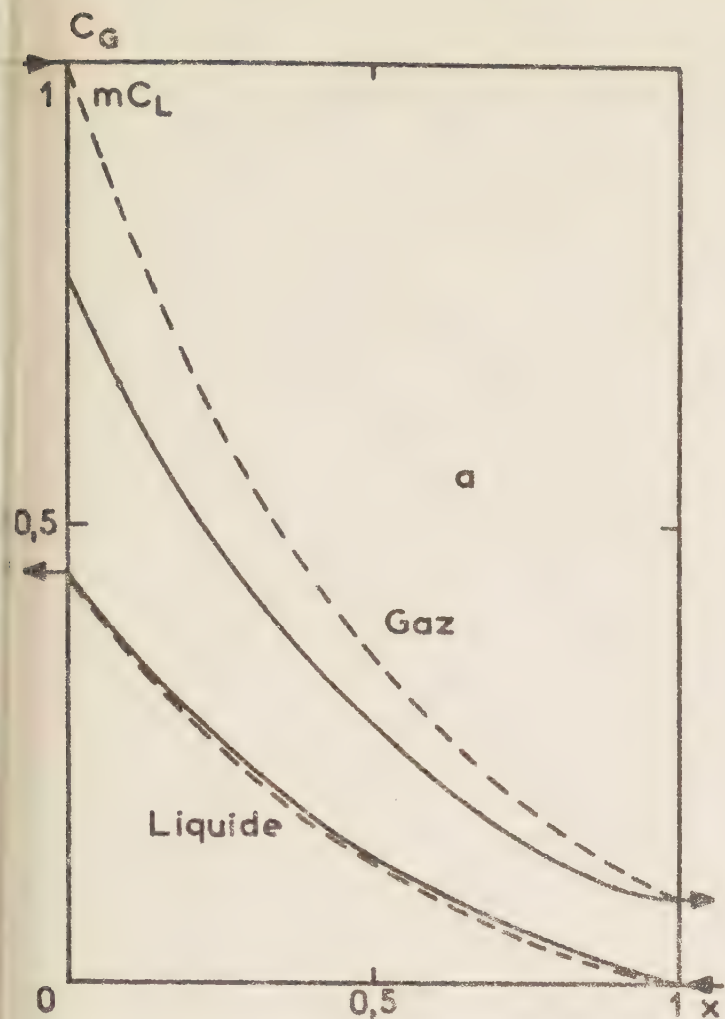
NOYE

Fig.	a	b	c
$(NUT_G)P$	3,52	3,14	2,26
$(NUT_G)V$	7,05	5,86	4,75
P_G	5,0	6,35	8,1
P_L	93	93	93
Λ	0,5	1,0	2,0

--- Ecoulement Piston

— Ecoulement Piston Diffusionnel

Fig. VIII.12



PROFILS DE CONCENTRATIONS
A.R. 6,4 mm

$L=16 \text{ Kg/m}^2.\text{sec}$

NOYE

Fig.	a	b	c
$(NUT_G)P$	3,52	2,02	1,24
$(NUT_G)V$	5,60	2,57	1,424
P_G	6,5	9,5	12,5
P_L	229	229	229
Λ	0,5	1,0	2,0

--- Ecoulement Piston
— Ecoulement Piston Diffusionnel

Fig. VIII.13

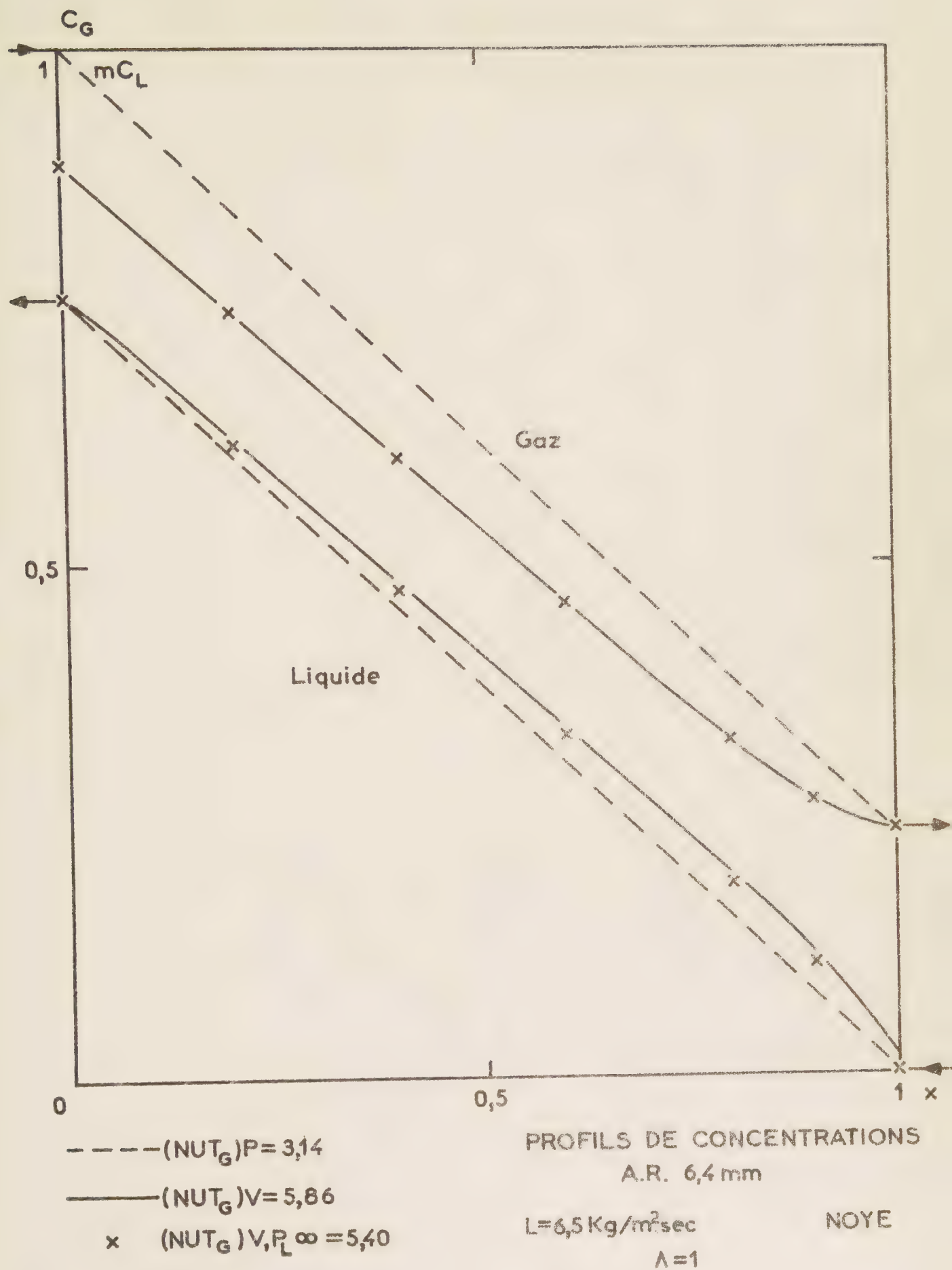


Fig. VIII.14

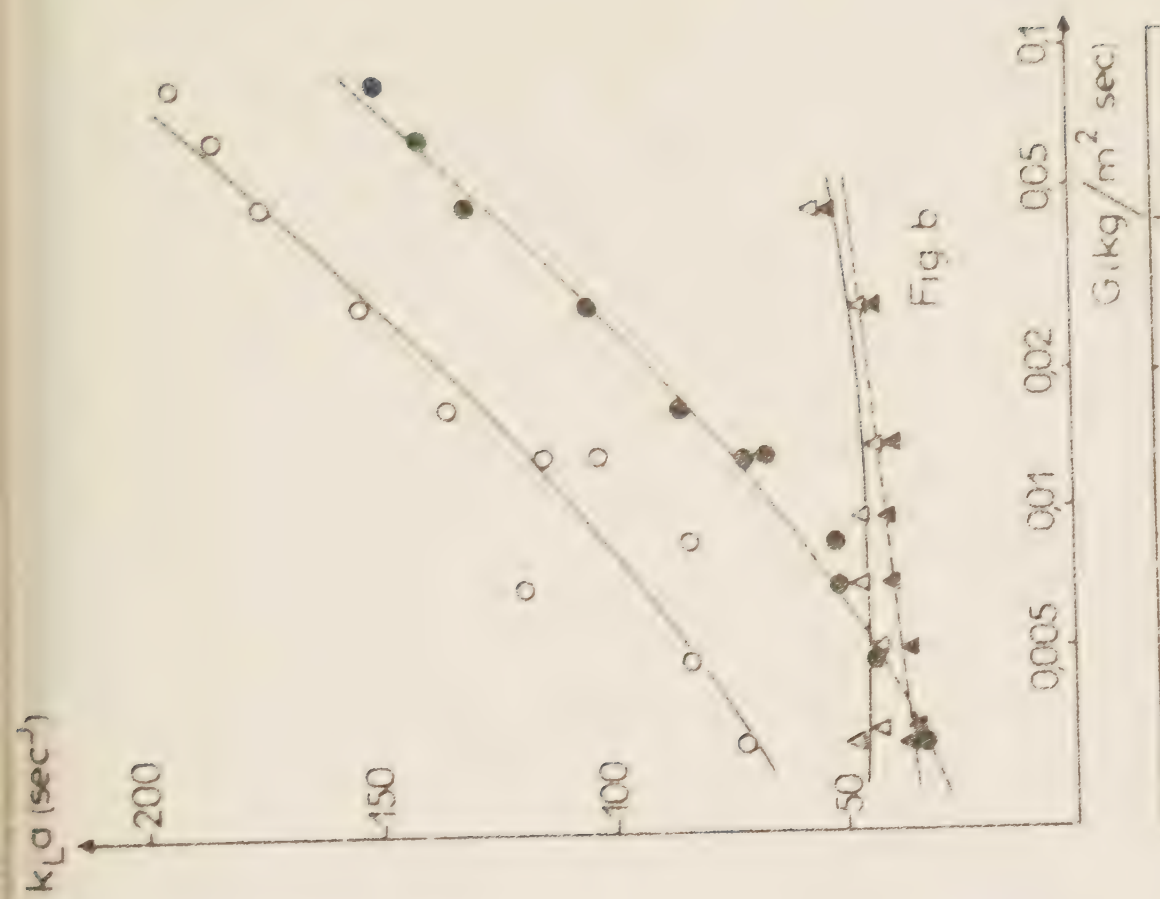
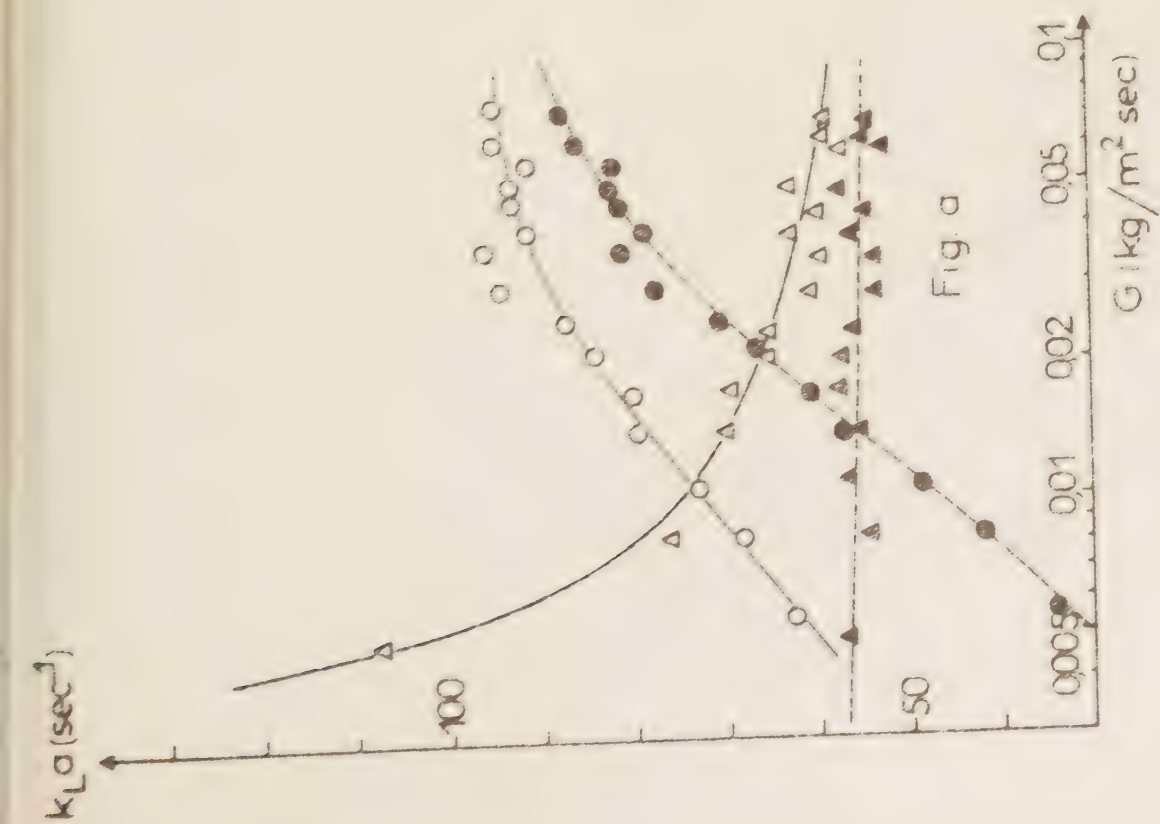
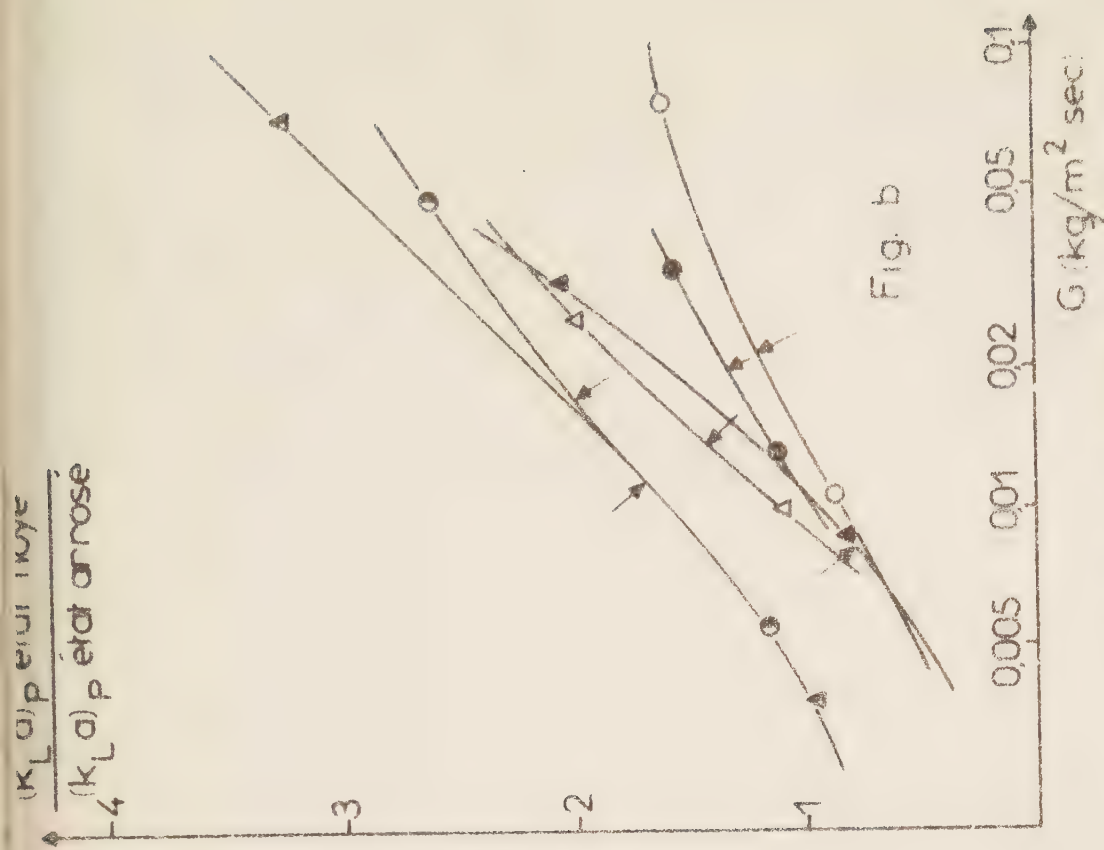
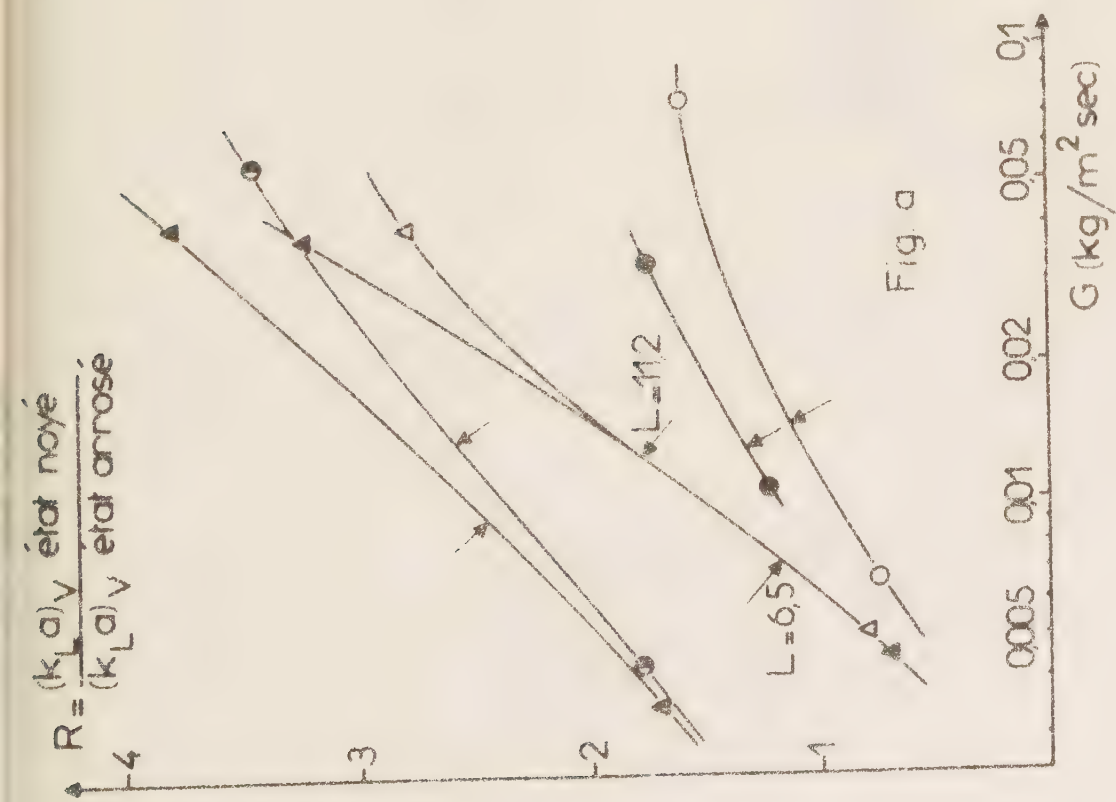


Fig.	Garnissage	L (mm)	$k_L a$ (sec ⁻¹)
a	AR	6.4	16
b	AR	10.3	11.1



INFLUENCE DE LA DISPERSION
AXIALE SUR $k_L a$



L	symbole	d mm
6,5	▲	AR 6,4
11,2	△	
14,9	●	
16	○	
6,95	▲	AR 10,3
11,11	●	
→	→	$\Lambda \approx 1$

COMPARAISON DES AIRES INTERFACIALES
DANS LES ETATS NOYÉS ET ARROSÉS

Fig. VIII.16

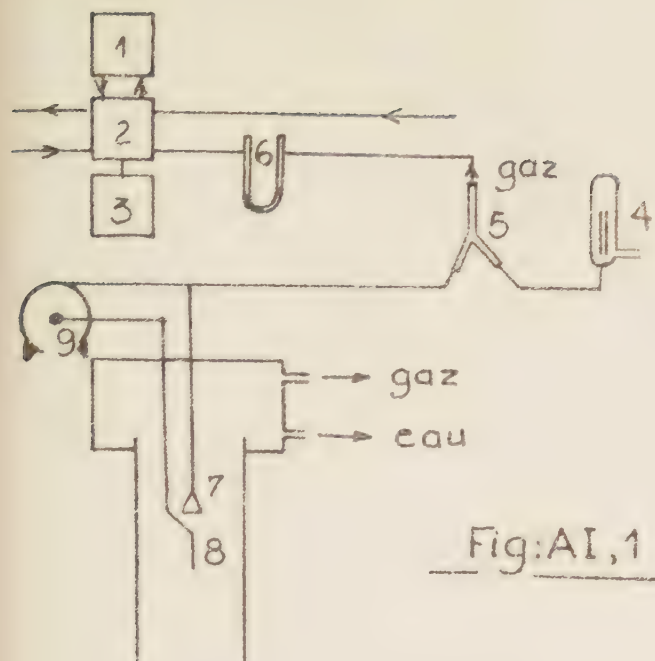


Fig: AI, 1

- 1 Thermostat
- 2 Cellules de mesure
- 3 Enregistreur
- 4 Niveau
- 5 Tube en verre: separation du
gouttelette d'eau perinertie.
- 6 Dessicateur à CaCl_2
- 7 Sonde conique: ouverture $\varnothing 20\text{mm}$
raccordée par un tuyau de $\varnothing 2\text{mm}$
fonctionnant sans aspiration
- 8 Sonde capillaire branchée sur
la vanne.
- 9 Pompe.

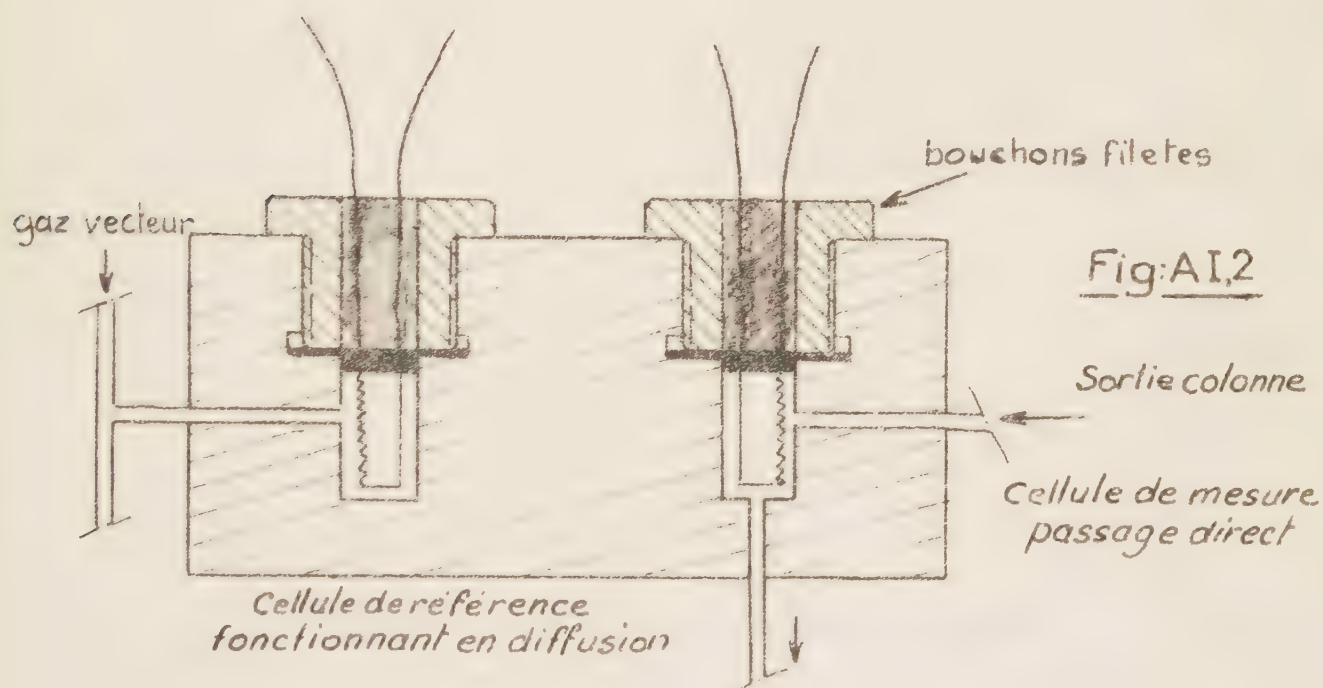


Fig: AI, 2



Fig: AI, 3

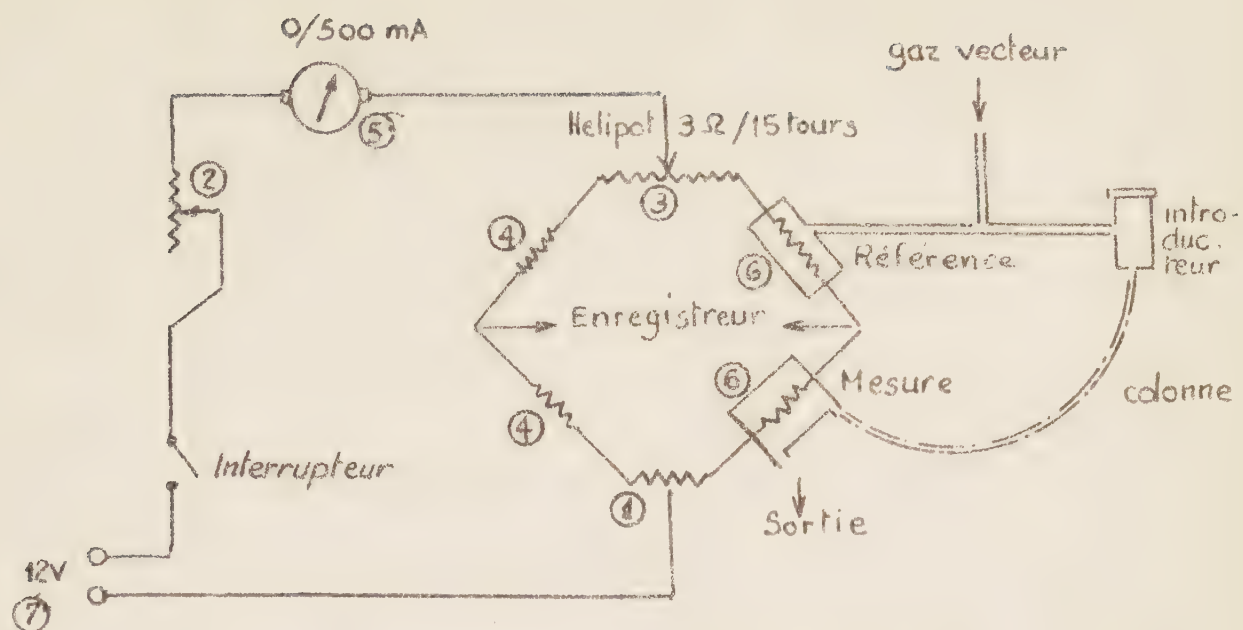


Fig: AI,4

- 1 - Potentiomètre de 10Ω
- 2 - Potentiomètre de 220Ω
- 3 - Potentiomètre de 3Ω 15 tours helicoidal
- 4 - 2 Résistances de 100Ω
- 5 - Milliampèremètre
- 6 - 2 filaments de cellule decatharomètre
- 7 - Batterie d'accumulateurs 12V/160AH

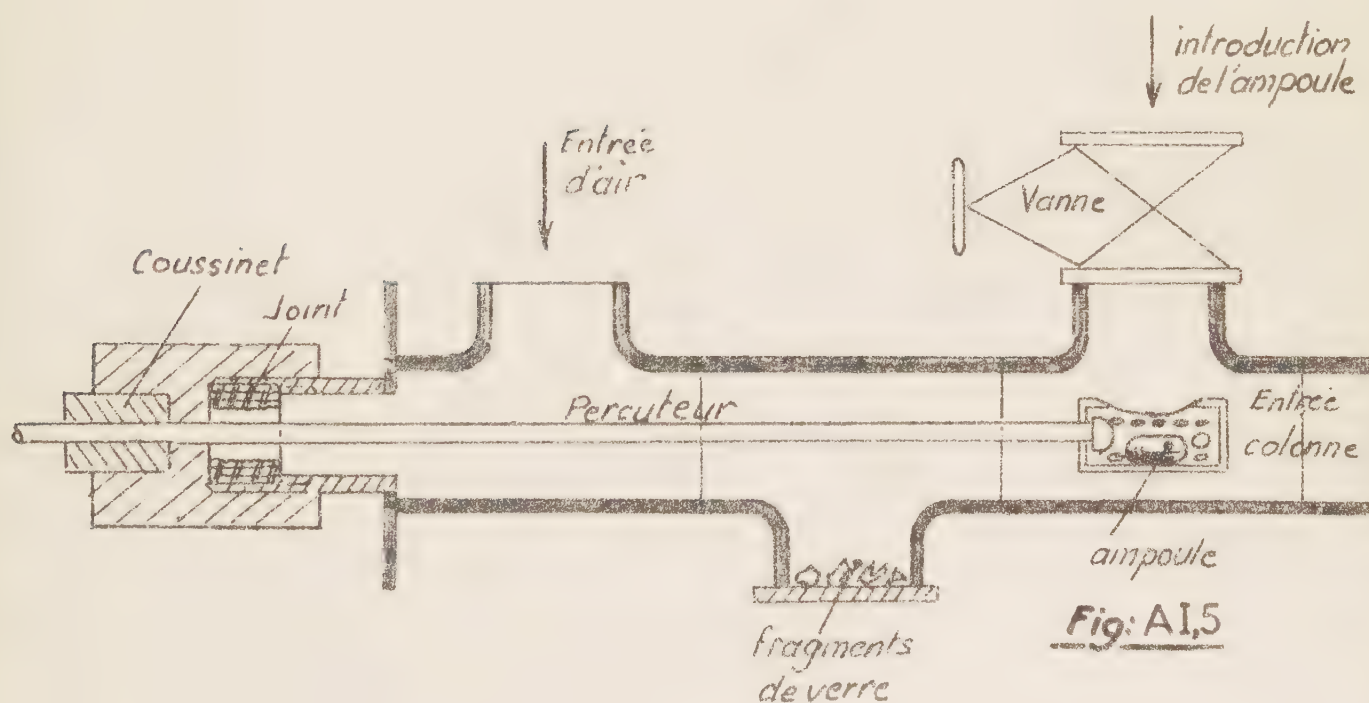


Fig: AI,5

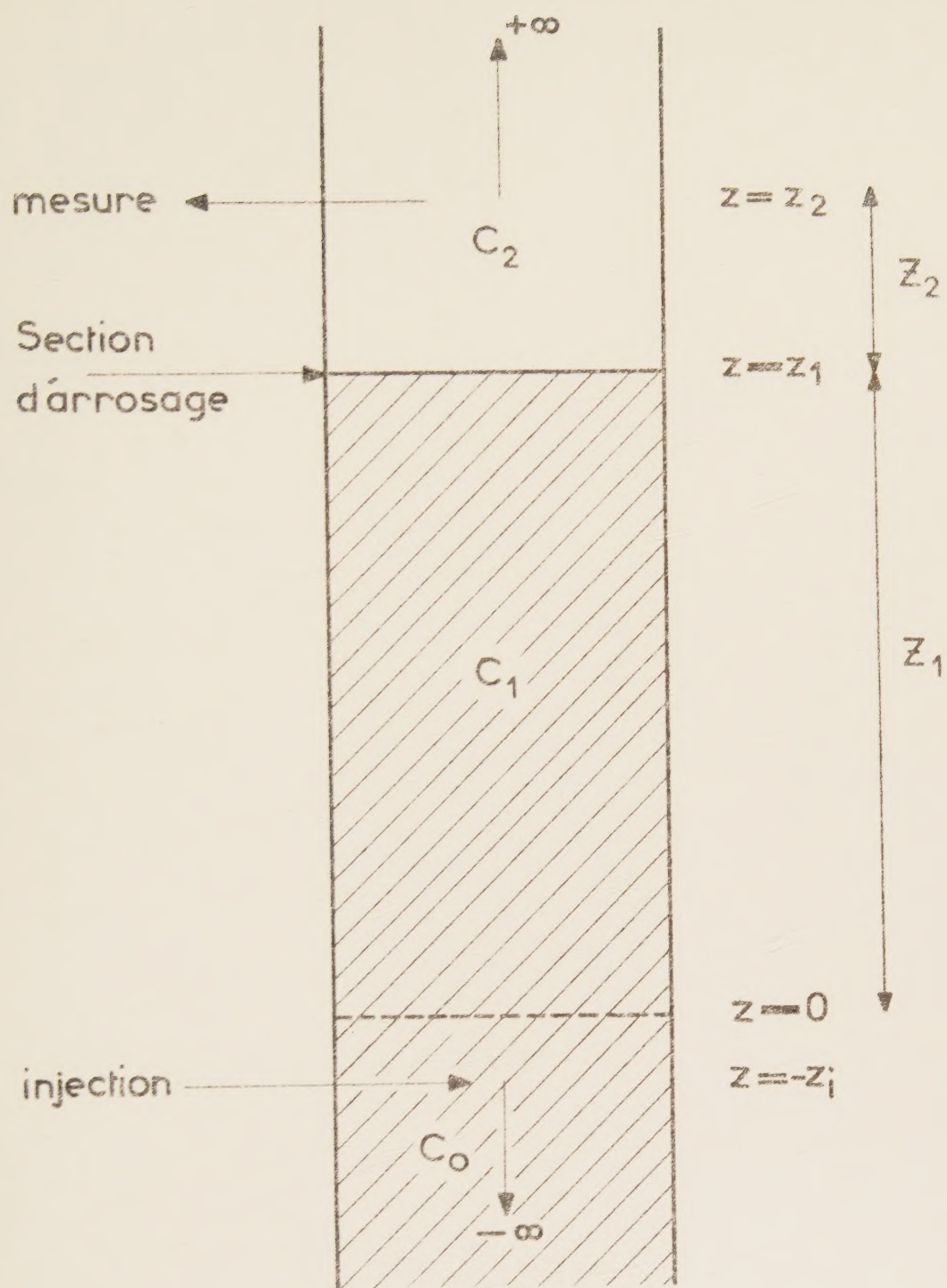


Fig. A IV,1

